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# मोबाइल सेवाओं में प्रयुक्त रेडियो उपस्कर के मापन की पद्धतियां

## भाग 6 चयनात्मक आह्वान तथा आंकड़ा उपस्कर

*Indian Standard*

# METHODS OF MEASUREMENT FOR RADIO EQUIPMENT USED IN THE MOBILE SERVICES

## PART 6 SELECTIVE-CALLING AND DATA EQUIPMENT

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
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# *Indian Standard*

# METHODS OF MEASUREMENT FOR RADIO EQUIPMENT USED IN THE MOBILE SERVICES

## PART 6 SELECTIVE-CALLING AND DATA EQUIPMENT

## NATIONAL FOREWORD

This Indian Standard which is identical with IEC Pub 489-6 ( 1987 ) 'Methods of measurement for radio equipment used in the mobile services — Part 6 : Selective-calling and data equipment' issued by the International Electrotechnical Commission ( IEC ), was adopted by the Bureau of Indian Standards on the recommendation of the Radio Communications Sectional Committee ( LTD 20 ) and approval of the Electronics and Telecommunication Division Council.

The text of the IEC Publication has been approved as suitable for publication as Indian Standard without deviations. Certain conventions, are however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.

b) Comma ( , ) has been used as a decimal marker while in Indian Standards, the current practice is to use a point ( . ) as the decimal marker.

## CROSS REFERENCES

In the adopted standard, reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards which are to be substituted in their place are listed below along with their degree of equivalence for the editions indicated:

| *International Standard* | *Corresponding Indian Standard* | *Degree of Equivalence* |
|---|---|---|
| IEC Pub 489-1 ( 1983 ) Methods of measurement for radio equipment used in the mobile services — Part 1 : General definitions and standard conditions of measurement | IS 10820 ( Part 1 ) : 1984 Methods of measurement for radio equipment used in the mobile services : Part 1 General definitions and standard conditions of measurement | Technically equivalent |

The concerned Technical Committee responsible for preparation of this standard has reviewed the provisions of the following International Publications and has decided that they are acceptable for use in conjunction with this standard.

IEC 315-1 ( 1970 ) : Methods of measurement on radio receivers for various classes of emission, Part 1 General conditions for measurements and measuring methods applying to several types of receivers

IEC Pub 315-2 ( 1971 ) : Methods of measurement on radio receivers for various classes of emission, Part 2 Measurements particularly related to the audio-frequency part of a receiver

IEC Pub 489-3 ( 1979 ) : Methods of measurement for radio equipment used in the mobile services, Part 3 Receivers for A3 and F3 Emissions

IEC Pub 489-5 ( 1987 ) : Methods of measurement for radio equipment used in the mobile services, Part 5 Receivers employing single-sideband techniques ( R3F, H3F or J3E )

The contents of Amendment No. 1 and 2 to IEC Pub 489-6 have been incorporated in this standard.

Only the English language text of the International Standard has been retained while adopting it in this Indian Standard.

## SECTION ONE — GENERAL

### 1. Scope

This standard is applicable to receivers used in the mobile services, for receiving (selective calling) (data) signals, having the following emission characteristics:

Type of modulation of the main carrier:

(A) amplitude double-sideband,
(H) single-sideband, full carrier,
(R) single-sideband, reduced or variable carrier,
(F) frequency modulation,
(G) phase modulation.

Nature of signal(s) modulating the main carrier:

(1) a single channel containing quantized or digital information without the use of a modulating sub-carrier,
(2) a single channel containing quantized or digital information with the use of a modulating sub-carrier,
(7) two or more channels containing quantized or digital information.

Type of information to be transmitted:

(A) telegraphy—for aural reception,
(B) telegraphy—for automatic reception,
(D) data transmission, telemetry, telecommand.

Details of signal(s) (fourth symbol, optional):

(A) two-condition code with elements of differing numbers and/or durations,
(B) two-condition code with elements of the same number and duration without error-correcting,
(C) two-condition code with elements of the same number and duration with error-correction,
(D) four-condition code in which each condition represents a signal element (of one or more bits),
(E) multicondition code in which each condition represents a signal element (of one or more bits),
(F) multicondition code in which each condition or combination of conditions represents a character.

*Note.* — See ITU Radio Regulations (Edition 1982), Article 4 and Appendix 6, for details and definition of the emission characteristics.

This standard is intended to be used in conjunction with IEC Publication 489-1. The terms and definitions and the conditions of measurement set forth in this standard are intended for type and acceptance tests.

The methods of measurement in this standard have the radio-frequency input signal modulated only with either a selective calling or data signal. Methods of measurement for a radio-frequency input signal modulated simultaneously with both a data signal and other signals (e.g. other data signals and/or voice) are under consideration.

Selective calling is usually used to select one or a group of receivers by conditioning the receivers(s) to deliver a voice message or to activate an alarm.

In this standard, the sub-clauses titled 'Method of measurement' are designed to measure the value of a radio-frequency parameter. In some cases it is only necessary to determine if the receiver-decoder is compliant with the radio-frequency parameter specification. This can usually be done more simply and with less effort than measuring the radio-frequency parameter. For the more frequently measured radio-frequency parameters, a compliance test method is included in the appropriate clauses. The specified value for the radio-frequency parameter will be the appropriate value specified by a regulation, contract or equipment specification.

## 2. Object

The object of this standard is to standardize the definitions, the methods and conditions of measurement used to ascertain the radio-frequency performance of selective calling or data receiver-decoder equipment, thus making possible meaningful comparisons of the results of measurements made by different manufacturers.

This standard will cover selective calling signals and three types of data signals:

*a)* bit streams,

*b)* character strings,

*c)* messages.

The methods of measurement for the radio-frequency parameters are appropriate for the three types of data signals. The measurements will be made using the port that provides signals for the intended application (excluding test ports).

To differentiate the radio-frequency parameters measured in this part of IEC Publication 489 from those in other parts of IEC Publication 489, the name of each parameter is followed by either "(selective calling)", "(bit stream)", "(character string)" or "(meassage)".

In Sections Four and Six, the general term "(data)" is used after each radio-frequency parameter. When equipment is measured, the proper data type "(bit stream)", "(character string)" or "(message)" will be substituted for "(data)".

## SECTION TWO — SUPPLEMENTARY DEFINITIONS AND CONDITIONS OF MEASUREMENT

### 3. Supplementary terms and definitions

For the purpose of this standard, the following supplementary terms and definitions apply.

3.1 *Standard calling probability*

An 80% probability of successful calling.

3.2 *Modulation depth*

For double-sided amplitude modulation, the modulation depth, in percent, is given by the following:

$$\text{Modulation depth} = \frac{(V_{\max} - V_{\min})}{(V_{\max} + V_{\min})} \times 100\%$$

where:

$V_{\max}$ is the peak-to-peak voltage at the crest of modulation
$V_{\min}$ is the peak-to-peak voltage at the valley of modulation

3.3 *Signal*

A physical phenomenon or characteristic quantity of such a phenomenon, whose time variation represents information.

3.4 *Coded signal*

That signal or group of signals that enables the performance of a unique calling function.

3.5 *Standard coded test signal (SCTS)*

For the purpose of these measurement, the standard coded test signal shall be defined in the equipment specification and will usually be generated by an encoder of the type associated with the decoder under test. The parameters of the coded test signal ( e. g., frequencies, pulse duration, pulse timing, etc ) shall have tolerances small enough to ensure that the results are not significantly influenced by them.

In addition to any other parameters, the equipment specification shall define the appropriate values for the permissible:

- maximum usable modulation depth of Type A modulation, or
- frequency/phase deviation of Type G or F modulation, or
- amplitude relationships between the carrier and the sidebands produced by Type H or R modulation.

3.6 *Coding system*

A system that permits the transmission of unique information from one point to another. Present techniques include phase coding, pulse coding, frequency coding and a combination of these.

3.7 *Encoder*

The apparatus in a selective-calling system that generates the coded signal for transmission.

3.8 *Decoder*

The apparatus in a selective-calling system which is intended to respond exclusively to a specific coded signal.

### 3.9 *Alarm*

In a selective-calling system, an alarm is any indication that any or all receivers and their associated decoders have received their intended coded signals.

*Note.* — The alarm may be a lamp, a "bleep" generated within the decoder, a vibrator, or only the opening of a mute or squelch circuit. The latter is usually indicated by an increase in the residual noise level at the output of the receiver.

### 3.10 *Selective-calling system*

A system whereby the transmission of a signal code from a station enables another predetermined station or group of stations to be called exclusively.

### 3.11 *Standard unwanted signal*

If the wanted signal has Type A modulation, then the standard unwanted signal should be modulated with 400 Hz at the modulation depth of 60%.

If the wanted signal has Type F or G modulation, then the standard unwanted signal should be modulated with 400 Hz at 60% of the maximum permissible frequency deviation.

For all other types of modulation of the wanted signal, the standard unwanted signal is not modulated.

### 3.12 *Selective-calling equipment*

Apparatus consisting of at least an encoder, decoder and the power supplies for the operation of the equipment.

If it is not possible to isolate the associated transmitter and receiver circuits from the encoder and decoder, they shall be considered as part of the selective-calling system.

### 3.13 *Radio pager*

A small radio receiver-decoder, which provides an alarm following reception of a selective call. It is intended to be worn on a person and usually has an integral antenna.

## 4. Standard test conditions

4.1 Unless otherwise stated, methods of measurements shall be performed under the general test conditions as stated in IEC Publication 489-1 and the supplementary test conditions given in Clause 5.

4.2 In this standard the methods of measurement have been developed under the assumption that automatic test equipment will be available.

4.3 If the data source and encoder are unique, the manufacturer shall supply to the organization making the measurements either detailed information so that the items can be manufactured, or the unique items themselves.

## 5. Supplementary test conditions

### 5.1 *Receiver-decoder having an integral antenna*

In this standard the methods of measurement and compliance tests have been written for receivers having antenna terminals. For receivers with integral antennas the following test conditions apply:

Concerning average radiation sensitivity ( selective calling ), Clause 7, measurements and compliance tests are made on a test site.

The measurements and compliance tests in Clauses 8 through 21 ( selective calling) and Clauses 23 through 30 ( data ) for receiver-decoders having an integral antenna are made with the receiver in a suitable radio-frequency coupling device ( RFCD ). The same procedures are used as for receivers having antenna terminals, except that the input signal level recorded is that introduced at the input terminals of the RFCD instead of at the antenna terminals of the receiver.

*Notes 1.* — The measurements and compliance tests in Clauses 8 through 21 ( selective calling ) and Clauses 23 through 30 ( data, message ) have been designed for non-automatic use: the number of trails in these measurements and compliance tests have been reduced to the minimum required to obtain the necessary accuracy and variation. Various automatic measurement procedures may be used, but it is not proposed that they be standardized in this standard at this time. However, the measurements and compliance tests in Clauses 23 through 30 ( data, bit stream and character string ) have been designed to use automatic test equipment.

*2.* — The measurements in Clauses 8 through 21 ( selective calling ) can be used for continuous signal ( e. g. continuous tone controlled squelch systems ) provided that a time for the operation of the decoder is specified ( e. g. 300 ms ).

### 5.2 *Input-signal arrangements for testing receivers equipped with suitable antenna terminals*

Depending on the type of modulation and the measuring equipment available, one of the three measuring arrangements described below shall be employed.

*a)* Arrangement A

The arrangement comprises the following pieces of equipment:

- a test data source and an encoder as required, or a test encoder combining these two functions,
- a radio-frequency signal generator or an alternate signal source ( see Sub-clause 6.9 ) capable of being modulated in accordance with the type of modulation used by the receiver,
- an impedance matching network ( or pad; see (3) of Figure 1) placed as close as possible to the receiver under test.

*Note.* — Examples of impedance matching networks and combining networks are given in Appendix A.

*b)* Arrangement B

For some types of single-sideband modulation, with corresponding characteristics as given in Item (1) of the Scope, it may be possible to simulate the modulated signal by using two radio-frequency generators. In this case, an arrangement similar to arrangement A may be used, but with the signal generator or alternate signal source replaced by two radio-frequency signal generators, the outputs of which are connected to a combining network terminated in an adjustable attenuator.

*c)* Arrangement C

The arrangement is similar to arrangement A, except that it also requires a means to convert the output frequency of the alternate signal source to the nominal frequency specified for the receiver. This is accomplished by using a radio-frequency signal generator and a frequency converter which is terminated in an adjustable attenuator.

Some measurements require an unwanted signal to be added. This signal is supplied by a radio-frequency signal generator connected to one of the inputs of a combining network which is inserted at a convenient place in the transmission line (2) shown in Figure 1.

The presentation of results shall state which of the arrangements A, B or C, has been used.

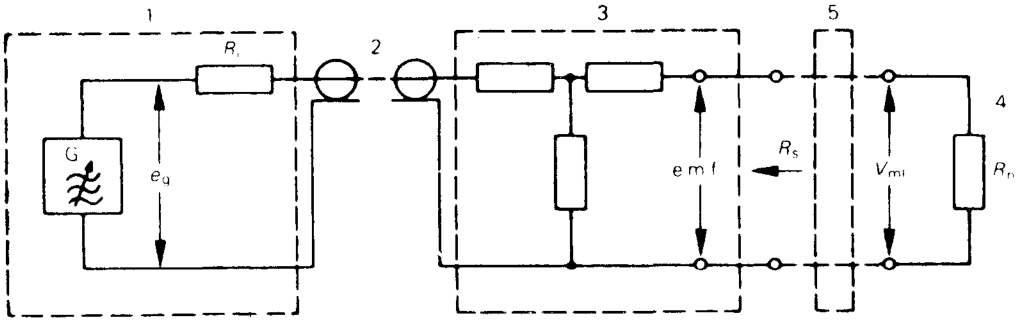
For arrangements A and C, the performance of the alternate signal source should be such that the receiver parameters may be measured up to values which are at least 10 dB greater than the receivers' specified values.

5.2.1 *Source impedance of the measuring arrangement for receivers requiring a specified source resistance*

This sub-clause applies to receivers which are connected to the antenna by means of a transmission line ( which is synonymous with 'feeder line') having a specific characteristic impedance for example equal to $R_n$, $R_n$ being the specified nominal radio-frequency input impedance of the receiver.

The source impedance $R_s$ of the measuring arrangement shown in Figure 1 shall be equal to the specified source resistance, or, in the absence of such specification, to the specified nominal radio-frequency input impedance $R_n$ of the receiver.

The nominal radio-frequency input impedance is that value stated by the manufacturer for which the equipment performance will be optimum when connected to an antenna or transmission line of the same impedance.



1 = radio-frequency signal generator with source impedance $R_i$
2 = transmission line
3 = impedance matching network ( pad )
4 = nominal input impedance of receiver: $R_n$
5 = artificial antenna ( where required )
$R_s$ = impedance of the input-signal source

FIG. 1. — Input-signal source test arrangement.

5.2.2 *Input-signal source for receivers tested with the aid of an artificial antenna*

This sub-clause is applicable to receivers intended to operate with an antenna having a complex impedance.

The input-signal source shall consist of a radio-frequency signal generator, a transmission line, an impedance matching network, and an artificial antenna. The characteristics of the artificial antenna shall be specified by the manufacturer of the receiver.

5.2.3 *Receivers tested with the aid of an artificial antenna*

The input-signal level is the e.m.f. of the source connected to the input terminals of an artificial antenna. It should be expressed in $\mu$V or dB ( $\mu$V ).

5.3 *Input-signal measuring convention*

5.3.1 *Receiver requiring a specified source resistance*

The input-signal level should preferably be determined by measuring the electromotive force present at the output terminals of the unterminated input-signal source ( e.m.f. of Figure 1 ).

Alternatively, the input-signal level may be determined by measuring the matched-load ( ml ) voltage across a resistance having a value equal to $R_s$.

The matched-load ( ml ) is one- half the value of the e.m.f.

When the input-signal level is determined with a voltmeter incorporated in the equipment supplying the input signal ( voltage $e_g$ in Figure 1 ), the loss of the impedance matching network and, if applicable, also the losses of the transmission line and any combining network and adjustable attenuators inserted in the transmission line shall be taken into account.

The presentation of results shall state which voltage has been recorded, for example, 2 $\mu$V ( e.m.f. ) or 1 $\mu$V ( ml ). The source resistance $R_s$ shall be stated with the results.

5.3.2 *Input-signal level*

In this standard, the input-signal levels of the wanted and unwanted signals shall be expressed in terms of r.m.s. values as follows:

- for angle ( Type G or F: phase or frequency ) modulation, including frequency-shift and phase-shift modulation or keying: the r.m.s. voltage of the signal, either modulated or unmodulated,
- for on-off modulation, or keying of a sinusoidal carrier which may or may not be modulated with an additional signal: the r.m.s. voltage of the continuous carrier, without modulation,
- for double-sideband amplitude (Type A) modulation with full carrier: the r.m.s. voltage of the unmodulated carrier,
- for single-sideband amplitude (Type H or R) modulation with full, reduced or variable carrier: the r.m.s. value of a sinusoidal voltage, the peak value of which is equal to the amplitude of one radio-frequency cycle at the crest of the envelope of the modulated wave.

The input-signal levels may be expressed in $\mu$V or dB ($\mu$V) and shall be determined in accordance with Sub-clause 5.2.

5.4 *Connections of the measuring equipment*

The data measuring equipment shall be connected to the port that provides signals for the intended application.

Care should be taken that the input impedance of the measuring equipment does not affect the loading conditions specified for the receiver.

5.5 *Standard input signal*

5.5.1 *Standard input signal (Type A, G or F modulation)*

A radio-frequency signal at standard input-signal level with standard modulation, at the standard input-signal frequency.

5.5.2 *Standard input signal (Type H or R modulation)*

A radio-frequency signal or linear combination of two radio-frequency signals from a signal source that simulates the single-sideband emission from a transmitter when it is modulated with an audio-frequency signal of 1 000 Hz.

The frequencies and the levels of the input signal are dependent upon the class of emission they represent. Two frequencies, one of which represents the carrier and the other the sideband, are chosen such that when demodulated they will produce an audio output at a frequency of 1 000 Hz.

The standard input-signal levels are:

| Class of emission | Signal representing | |
|---|---|---|
| | carrier | sideband |
| R3E<br>H3E | + 42 dB (μV)<br>+ 54 dB (μV) | + 60 dB (μV)<br>+ 54 dB (μV) |

5.6 *Standard input-signal level*

Unless otherwise specified, the standard input-signal level for a receiver of the type considered in this standard is 60 dB (μV) (e.m.f.) or 54 dB (μV) (ml).

5.7 *Standard input-signal frequency*

For all tests, except where otherwise specified, the standard input-signal frequency is one of the specified nominal frequencies. For S.S.B. type of modulation, the nominal frequency is the frequency of the carrier.

5.8 *Standard modulation of an input signal*

The modulation due to an input signal of 1 000 Hz at a level to produce:

a modulation depth of 30%;

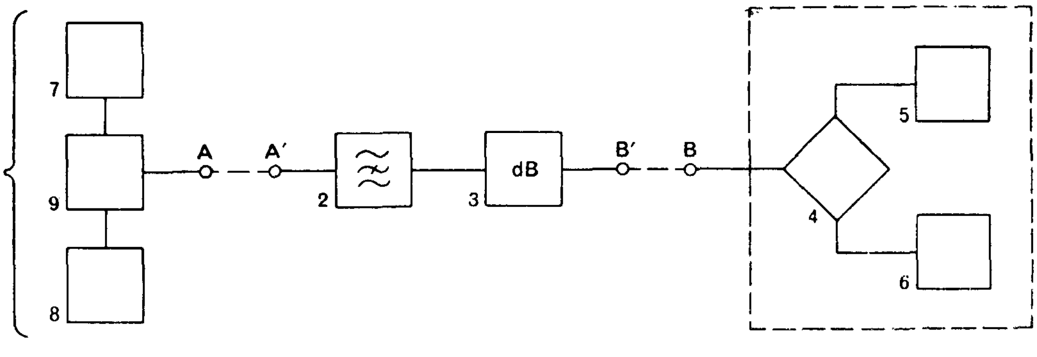
60% of maximum permissible frequency (or phase) deviation.

5.9 *Input-signal arrangements for testing the receiving part of equipment for duplex operation*

When the performance of the receiving part of equipment for duplex operation is to be evaluated while the associated transmitting part is operating, precautions should be taken in order to ensure that the operation of the signal generator or generators used for testing the receiving part is not affected by the radio-frequency signal of the transmitting part and that the latter is terminated by its proper load impedance.

5.9.1 *Input-signal source*

An example of a suitable arrangement for marking measurements on receivers of equipment for duplex operation is shown in Figure 2.



1 = input-signal source
2 = band-stop filter
3 = attenuator
4 = combining unit belonging to the equipment under test
5 = transmitting part of the equipment
6 = receiving part of the equipment
7 = radio-frequency signal generator
8 = radio-frequency signal generator
9 = radio-frequency combining network

FIG. 2. — Example of an arrangement for testing receivers for duplex operation.

Connect the input-signal source (1) (levels adjusted in accordance with Sub-clause 5.3) to point A'. The centre frequency of the band-stop filter (2) is adjusted to the operating frequency of the transmitter under test.

The impedance at point B' shall be such that the transmitting part is operating under the specified matched conditions. To ensure that the V.S.W.R. will be less than 1.25, irrespective of any mismatch caused by the band-stop filter (2) and the combining unit (4), the attenuation of the attenuator (3) should be at least 30 dB. It should be noted that the attenuator will dissipate nearly all of the power from the transmitting part and therefore shall have suitable power-handling capability.

### 5.9.2 *Input-signal level*

The level of the radio-frequency input signal shall be determined at point B' of Figure 2.

### 5.9.3 *Input-signal location*

The radio-frequency input signal shall be determined at point B' of Figure 2.

## 6. Characteristics of the measuring equipment

Where necessary ( for measuring equipment which may not be commercially available ), and to ensure that different operators at different locations will obtain similar results when measuring the same receiver, certain characteristics of the measuring equipment and test sites have been specified. Procedures for verifying that the measuring equipment meets these specifications are also given.

### 6.1 *Signal generator intermodulation characteristics*

A method for identifying intermodulation between signal generators, the outputs of which are combined, is given in Appendix B.

### 6.2 *Signal generator noise characteristics*

A method for identifying signal generator noise is given in Appendix B.

### 6.3 *Selective measuring device*

The selective measuring device may be a frequency selective voltmeter, a spectrum analyzer, or a calibrated field-strength meter. The bandwidth of the measuring device shall be appropriate for the measurement being made or shall be adjusted to the value stated in the method of measurement.

### 6.4 *Radio-frequency coupling device (RFCD) Characteristics and measurements*

The measurement in this standard are applicable to receivers having either antenna terminals or an integral antenna.

Measurements of the radio-frequency parameters of receivers having an integral antenna are performed in an RFCD. When making these measurements, precautions shall be taken to ensure that:

— the receiver is adequately shielded from electromagnetic disturbance;

— the attenuation of the coupling between the radiation source and the receiver being measured is sufficiently low, stable and constant throughout the measuring frequency range.

The coupling loss depends on the particular measuring arrangement, the frequency being used, and the receiver being measured. Normally it is not precisely measured as it will only be useful for a particular measuring arrangement and frequency.

The coupling loss shall be sufficiently low so that the output power requirements of the singal generators used in this standard will not exceed the power output capability of commercially available signal generators.

To ensure measurement repeatability, an RFCD which includes the following should be used in the measurement arrangement:

— a radiating element;

— a radio-frequency input terminal connected to the radiating element through a transmission line;

— a means to ensure that the input impedance of the RFCD be the same as the impedance of the transmission line from the radio-frequency signal generator;

— a means for positioning the receiver being measured in a precise, repeatable and stable manner;

— a means to ensure that the presence of the person making the measurement does not affect the results.

It shall also have the following characteristics:

— a coupling loss between the radio-frequency input terminal and the receiver being measured of less than 30 dB;

— a coupling loss variation over the frequency range used in the measurement which does not exceed 2 dB;

— no non-linear elements which can affect the measurement results.

### 6.5 *Combining networks*

Examples of combining networks are given in Appendix A.

### 6.6 *Rayleigh fading simulator characteristics*

Appendix C contains the following items:

— an example of a Rayleigh fading simulator;

— specifications for the required parameters;

— a method of measurement for the required parameters.

### 6.7 *Characteristics of radiation test sites*

Appendix E provides a guide for the construction of a 30 m radiation test site for equipment receiving radio-frequency electromagnetic energy and a method for calibrating the test site.

Appendix K provides a guide for the construction of a 30 m radiation test site for equipment emitting radio-frequency electromagnetic energy.

Appendix L provides a guide for the construction of a 3 m radiation test site for measurements above 100 MHz of equipment emitting radio-frequency electromagnetic energy.

### 6.8 *Simulated man*

A simulated man is required when the average radiation sensitivity (selective calling) of a radio pager is measured. A description of a simulated man and its use is given in Appendix H.

### 6.9 *Alternate signal source*

For certain measurements, it may not be possible to modulate a radio-frequency signal generator to produce the necessary input signals, for example for single-sideband. In these circumstances, a transmitter may have to be used as an alternate signal source for the wanted or unwanted signal.

Some measurements require that the frequency be moved. A local oscillator, balanced mixer and filters may be used to make the frequency translation.

The characteristics of the alternate signal source should be such that receiver parameters may be measured up to values which are at least 10 dB greater than the receivers' specified values.

Care must be taken to shield the receiver from the transmitter.

### 6.10 *Signal generators*

Signal generators are normally characterized for sinewave modulation and application of non-sinusoidal waveforms which are often encountered in the transmission of data may lead to monitoring or modulation problems. Such problems can affect the overall accuracy of any measurements that are made.

### 6.10.1 *Monitoring problems*

If the signal generator is provided with a voltmeter system to monitor the applied external modulation signal the readings may be in error when non-sinusoidal waveforms are applied. It is recommended that an oscilloscope be used to monitor the peak voltage of the applied data signal and that the level be adjusted to be equal to the amplitude of a pure sine wave which would produce the required modulation condition. If the signal generator monitor shows the same indication on both input signal conditions, then the user can be confident that inaccuracies due to monitoring will not be a problem.

### 6.10.2 *Modulating problems*

The signal generator modulating system will have finite bandwidth which is determined by high-pass and low-pass filters. The high-pass filter can introduce phase and amplitude errors at low frequencies and the user should assess the suitability of the instrument from the data provided by the manufacturer. In some circumstances, a signal source with a response extending down to a sufficiently low frequency (e.g. 1 Hz) will be satisfactory.

The effect of the low-pass filter on the signal source will be most noticeable when modulating signals with fast rise and fall times are applied. Depending on the characteristics of the filters, the modulation applied to the carrier signal will exhibit overshoot or degradation of the rise and fall times. In practice, these problems can be eliminated by filtering the modulating signal before it is applied to the signal generator, so that the test source correctly simulates a narrow-band transmitter.

## SECTION THREE — MEASUREMENTS OF RECEIVER-DECODER RADIO-FREQUENCY PARAMETERS ( SELECTIVE CALLING )

### 7. Average radiation sensitivity ( selective calling )

This measurement is only applicable to receivers with integral antennas.

### 7.1 *Definition*

The average of eight field strength measurements at a specified frequency with standard coded test signals (SCTS) each producing the standard calling probability when the receiver under test is rotated in 45° azimuth increments starting at the reference azimuth.

*Note.* — This parameter is sometimes called "signalling sensitivity".

7.2 *Method of measurement*

This measurement shall be made on a suitable radiation test site. See Appendix E for details and test site calibration procedure.

*a)* Calibrate the radiation test site at the standard input-signal frequency in accordance with Appendix E (Sub-clauses E 10.1 to E 10.4) for a field strength of 100 $\mu$V/m [40 dB ($\mu$ V/m)].

*b)* Connect the equipment as illustrated in Figure Elb.

*Note.* — For receivers normally worn on the body (e.g. radio pagers) use the simulated-man test fixture of Appendix H.

*c)* Modulate the radio-frequency signal generator (1) with the SCTS.

*d)* Orient the equipment so that a face is normal to the direction of the transmitting antenna (2) (see Appendix E, Clause E 3). This determines the referenceazimuth.

*e)* Transmit the SCTS and confirm that the receiver-decoder is functioning.

*f)* Set step attenuator (5) to a value which will produce a low calling probability (e.g. less than 10%).

*g)* Transmit the SCTS repeatedly and adjust the step attenuator (5) according to the following rules:

*h)* 1) Transmit the SCTS a maximum of four times, terminating the transmission sequence, however, if the receiver-decoder fails to recognize the signal any one of those times. Adjust the step attenuator (5) according to Step *h)* 2 ) or *h)* 3), whichever is appropriate.

2) If the receiver-decoder fails to recognize either the first, second, third, or fourth SCTS, decrease the attenuation of step attenuator (5) by 1 dB, and repeat Step *h)* 1 ).

3) If the receiver-decoder recognizes the four SCTSs, record the attenuation value of step attenuator (5) in decibels, and proceed to Step *i)*.

*Note.* — A careful study of the example in Figure Fl, page 128, of Appendix F, is recommended to avoid the possibility of misunderstanding Step *h)*.

*i)* Change the azimuth by 45° and repeat Steps *f)* to *h)*.

*j)* Repeat Step *i)* until attenuation values have been recorded for eight different positions.

7.3 *Presentation of results*

*a)* Convert the eight attenuation values to field strength values using:

$$\mu V = 100 \cdot 10^{(20 - \text{“dB”})/20} \, \mu V/m$$

where “dB” is the attenuation value recorded in Step *h)* 3) of Sub-clause 7.2.

*b)* Calculate the arithmetic mean of the eight field strength values. This is the average radiation sensitivity ( selective calling ) which may be expressed as $\mu$V/m or dB ( $\mu$V/m ).

7.4 *Compliance test method*

This measurement shall be made on a suitable radiation test site (see Appendix E for details and calibration procedure of the test site).

*a)* Calibrate the radiation test site at the standard input-signal frequency in accordance with Appendix E (see Sub-clauses E10.1 through E10.4) for a field strength of 100 $\mu$V/m [40 dB ($\mu$V/m)].

*b)* Connect the equipment as illustrated in Figure E1b.

*c)* Adjust step attenuator (5) from 20 dB to:

$$\text{attenuation} = 20 + 20 \log \frac{100\mu\ \text{V/m}}{\text{specified field strength in } \mu\text{V/m}}\ \text{dB}$$

*d)* Orient the equipment so that a face is normal to the direction of the transmitter antenna (2) (see Appendix E, Clause E3). This determines the reference azimuth.

*e)* Transmit the standard coded test signal (SCTS) 18 times. If the receiver-decoder fails to recognize four or more SCTS's record a failure at this azimuth; otherwise record a pass.

*Note.* — The test at this azimuth may be stopped after four SCTS's have failed to be recognized.

*f)* Change the azimuth by 45° and repeat Step *e)*.

*g)* Repeat Step *f)* until passes or failures have been recorded for eight different positions.

*h)* If five or more of the positions were recorded as a pass in Step *e)*, record that the equipment does comply with the average radiation sensitivity (selective calling) specification; otherwise record that it does not comply.

## 8. Reference sensitivity ( selective calling )

### 8.1 *Definition*

The reference sensitivity ( selective calling ) is the level of the receiver-decoder input signal at a specified frequency, modulated with the SCTS, which will result in the standard calling probability.

RFCD reference sensitivity ( selective-calling ) is the level of the RFCD input signal at a specified frequency, modulated with the standard coded test signal, which will result in the standard calling probability.

### 8.2 *Method of measurement*

In this standard, reference sensitivity ( selective calling ) will be interchanged with RFCD reference sensitivity ( selective calling ) when the receiver-decoder is measured in an RFCD. The reference sensitivity ( selective calling ) shall be determined before the measurements in Clauses 10, 12, 13, 14, 15 and 16 can be made. An RFCD should be used for those measurements that require a ratio of two input signal levels and for those where the receiver-decoder being measured has an integral antenna. It is essential that the receiver remain in exactly the same position in the RFCD for all RFCD measurements. The measuring arrangement required for Clauses 9, 12, 13, 14 and 15 should be set up at the same time and should not be changed until the measurements are completed. The measuring procedure is as follows:

*a)* Connect the equipment as illustrated in Figure 3, with the switches in position b.

*b)* Modulate the radio-frequency signal generator (2) with the SCTS.

*c)* Apply to the step attenuator (3) a signal having the standard input-signal frequency at a level of approximately 60 dB ( $\mu$V ). Record this level.

If an RFCD is being used, the level in dB ( $\mu$V ), at the input of the RFCD, should be 60 dB greater than the coupling loss.

*d)* Set the step attenuator (3) to a low value, transmit the SCTS and confirm that the decoder is functioning.

*e)* Increase the step attenuator (3) to a value which will produce a low calling probability (e. g., less than 10%).

*f)* Transmit the SCTS repeatedly and adjust the step attenuator (3) according to the following rules:

*g)* 1) Transmit the SCTS a maximum of three times, terminating the transmission sequence, however, if the receiver-decoder fails to recognize the signal any one of those times. Adjust the step attenuator (3) according to Step *g)* 2) or *g)* 3), whichever is appropriate.

2) If the receiver-decoder fails to recognize either the first, second or third SCTS, decrease the attenuation of (3) by 1 dB, and repeat Step *g)* 1).

3) If the receiver-decoder recognizes the three SCTSs, record the attenuation value in decibels, increase the attenuation of (3) by 1 dB, record the new attenuation value in decibels, and proceed to Step *h)* 1 ).

*h)* 1) Transmit the SCTS a maximum of three times, terminating the transmission sequence, however, if the receiver-decoder fails to recognize the signal any one of those times. Adjust the step attenuator (3), according to Step *h)* 2) or *h)* 3), whichever is appropriate.

2) If the receiver-decoder fails to recognize either the first, second or third SCTS, decrease the attenuation of (3) by 1 dB, record the new attenuation value in decibels, and repeat Step *h)* 1).

3) If the receiver-decoder recognizes the three SCTSs, increase the attenuation of (3) by 1 dB, record the new attenuation value in decibels, and continue the SCTS transmission procedure in Step *h)* 1) until the total number of Step *h)* 1) transmissions is 20.

*Note.* — A careful study of the example in Figure F2, page 128, of Appendix F, is recommended to avoid the possibility of misunderstanding Steps *g)* and *h)*.

### 8.3 *Presentation of results*

*a)* Calculate the average of the attenuation values recorded in decibels in Steps *g)* and *h)* of Sub-clause 8.2.

*b)* The reference sensitivity ( selective calling ) is:

Reference sensitivity ( selective calling ) = $A - B - C$ dB ( $\mu$V )

If the measurement is made in an RFCD, the RFCD reference sensitivity (selective calling) = $A - B - C$ dB ( $\mu$V )

where:

$A$ is the output level of the radio-frequency signal generator (2) in dB ( $\mu$V )
$B$ is the loss of the combining network (4) in decibels
$C$ is the average of the attenuation values calculated in Step *a )* in decibels

### 8.4 *Compliance test method*

For compliance testing purposes, the test method described is that of sensitivity (selective calling) and applies to receiver-decoders that have an antenna terminal.

*Note.* — This test method does not provide a method of a measurement of reference sensitivity (selective calling). For the method of measurement of reference sensitivity (selective calling), see Sub-clause 8.2.

*a)* Connect the equipment as illustrated in Figure 3, with switches in position b. The attenuator (3) is either not connected or is set to zero attenuation.

*b)* Modulate the radio-frequency signal generator (2) with the the standard coded test signal (SCTS).

*c)* Apply to the input of the receiver-decoder (10) a signal at the standard input signal frequency at the specified signal level.

*d)* Transmit the SCTS 18 times. If the receiver-decoder fails to recognize four or more SCTS's record that the receiver decoder does not comply with the sensitivity ( selective calling ) specification; otherwise record that it does comply.

*Note.* — The test may be stopped after four SCTS's have failed to be recognized.

## 9. Adjacent radio-frequency signal selectivity ( selective calling )

### 9.1 *Definition*

The ability of the receiver-decoder to prevent an unwanted adjacent signal from degrading the desired response at the output of the receiver-decoder.

It is the ratio, expressed in decibels of:

*a)* the level of an unwanted input signal that causes a wanted input signal, which is 3 dB in excess of the reference sensitivity ( selective calling ), to produce a calling probability equal to the standard calling probability, to

*b)* the reference sensitivity ( selective calling ).

### 9.2 *Method of measurement*

*Note.* — The value of the reference sensitivity ( selective calling ) determined in Sub-clause 8.3 is required for this measurement.

*a)* Connect the equipment as illustrated in Figure 3, with the switches in position b.

*b)* Modulate the radio-frequency signal generator (2) with the SCTS.

*c)* In the absence of the unwanted signal, apply a signal from the radio-frequency signal generator (2) at the standard input-signal frequency so that the level at the input of the receiver-decoder is 3 dB in excess of the reference sensitivity ( selective calling ) determined in Sub-clause 8.3. Record this value.

*d)* Adjust the radio-frequency signal generator (6) and the audio-frequency generator (5) to produce standard modulation of the unwanted signal in accordance with Sub-clause 3.11.

If 400 Hz is present in the encoded signal (1) and if the unwanted signal is modulated with 400 Hz, use some other frequency between 300 Hz and 500 Hz to modulate the unwanted signal ( see Sub-clause 3.11 ).

*e)* Adjust the level of the radio-frequency signal generator (6) to a high value, for example, 80 dB ( $\mu$V ), and set its frequency to a specified increment higher or lower than the standard input-signal frequency. Record this level in dB ( $\mu$V ).

*f)* Decrease the step attenuator (9) to a value which will produce a low calling probability ( e.g., less than 10% ).

*g)* Transmit the SCTS repeatedly and adjust the step attenuator (9) according to the following rules:

*h)* 1) Transmit the SCTS a maximum of three times, terminating the transmission sequence, however, if the receiver-decoder fails to recognize the signal any one of those times. Adjust the step attenuator (9) according to Step *h)* 2) or *h)* 3), whichever is appropriate.

2) If the receiver-decoder fails to recognize either the first, second or third SCTS, increase the attenuation of (9) by 2 dB, and repeat Step *h)* 1).

3) If the receiver-decoder recognizes the three SCTSs, record the attenuation value in decibels, decrease the attenuation of (9) by 1 dB, record the new attenuation value in decibels, and proceed to Step *i)* 1).

*i)* 1) Transmit the SCTS a maximum of three times, terminating the transmission sequence, however, if the receiver-decoder fails to recognize the signal any one of those times. Adjust the step attenuator (9), according to Step *i)* 2) or *i)* 3), whichever is appropriate.

2) If the receiver-decoder fails to recognize either the first, second, or third SCTS, increase the attenuation of (9) by 1 dB, record the new attenuation value in decibels, and repeat Step *i)* 1).

3) If the receiver-decoder recognizes the three SCTSs, decrease the attenuation of (9) by 1 dB, record the new attenuation value in decibels, and repeat the SCTS transmission procedure in Step *i)* 1) until the total number of Step *i)* 1) transmissions is 40.

*Notes 1.* — A careful study of the example in Figure F4, page 130, of Appendix F is recommended to avoid the possibility of misunderstanding Step *h)* and *i)*.

2. — In this step the SCTS is transmitted 40 times.

*j)* Steps *e)* to *i)* may be repeated for other unwanted signal frequencies.

9.3 *Presentation of results*

*a)* Calculate the average of the attenuation values recorded in Step *h)* and *i)* of Sub-clause 9.2.

*b)* The adjacent radio-frequency signal selectivity ( selective calling ), in decibels is:

$$A - B - C - D - E$$

where:

$A$ is the output level of the radio-frequency signal generator (6) recorded in Step *e)* of Sub-clause 9.2 in dB ( $\mu$V )

$B$ is the loss of the combining network (7) in decibels

$C$ is the loss of the combining network (4) in decibels

$D$ is the average attenuation value calculated in Step *a*) of this Sub clause in decibels

$E$ is the reference sensitivity ( selective calling ) in dB ( $\mu$V ) determined in Sub-clause 8.3

*c)* Record in a table the values of the departure from the standard input signal frequency of the unwanted signal frequency and the adjacent radio-frequency signal selectivity ( selective calling ).

*d)* Record the reference sensitivity ( selective calling ) in dB ( $\mu$V ) the standard input-signal frequency, and the characteristics of the standard unwanted signal used. If 400 Hz is not used to modulate the unwanted signal, record the frequency used.

9.4 *Compliance test method*

*Note.* — The value of the reference sensitivity (selective calling) determined in Sub-clause 8.3 is required for this test.

*a)* Connect the equipment as illustrated in Figure 3, with switches in position b. Attenuators (3) and (9) are either not connected or are set to zero attenuation.

*b)* Modulate the radio-frequency signal generator (2) with the standard coded test signal (SCTS).

*c)* In the absence of the unwanted signal, apply a signal from the radio-frequency signal generator (2) at the standard input signal frequency so that the level at the input of the receiver-decoder is 3 dB in excess of the reference sensitivity (selective calling) determined in Sub-clause 8.3. Record this value.

*d)* Adjust the audio-frequency signal generator (5) to modulate the radio-frequency signal generator (6) with the standard modulation of the unwanted signal.

If 400 Hz is present in the encoded signal and if the unwanted signal is to be modulated (see Sub-clause 3.11), use a frequency between 300 and 500 Hz, other than 400 Hz, to modulate the unwanted signal.

*e)* Set the frequency of radio-frequency generator (6) to a specified increment higher or lower than the standard input-signal frequency, and adjust its level to apply to the receiver the specified unwanted signal level. Record the frequency and the level of the unwanted signal.

*f)* Transmit the SCTS 33 times. If the receiver-decoder fails to recognize seven or more SCTS's, record that the receiver-decoder does not comply with the adjacent radio-frequency signal selectivity ( selective calling ) specification, otherwise record that it does comply.

*Note.* — The test may be stopped after seven SCTS's have failed to be recognized.

*g)* Steps *e)* and *f)* may be repeated for other unwanted signal frequencies.

## 10. Adjacent-channel selectivity ( selective calling )

When mobile radio services use discrete channel spacings, the value of adjacent radio-frequency signal selectivity ( selective calling ) measured for a signal spacing equal to the discrete channel spacing may be quoted as the value of the adjacent-channel selectivity ( selective calling ). Adjacent-channel selectivity ( selective calling ) is measured using the method of measurement given in Clause 9.

## 11. Co-channel interference rejection and blocking ( selective calling )

Co-channel interference rejection ( selective calling ) is a particular case of adjacent radio-frequency signal selectivity ( selective calling ) where the difference between the unwanted signal frequency and the standard input-signal frequency is a specified amount less than 300 Hz. It is measured using the method of measurement given in Clause 9.

Blocking (selective calling) is a particular case of co-channel interference rejection (selective calling) where the difference between the unwanted signal frequency and the standard input-signal frequency is a specified amount greater than 1% of the standard input-signal frequency. It is measured using the method of measurement given in Clause 9.

## 12. Spurious response immunity ( selective calling )

*Note.* — This method is under consideration for receivers having an integral antenna using an RFCD.

### 12.1 *Definition*

The ability of the receiver-decoder to prevent a single unwanted spurious signal from degrading the desired response at the output of the receiver-decoder.

It is the ratio, expressed in decibels, of:

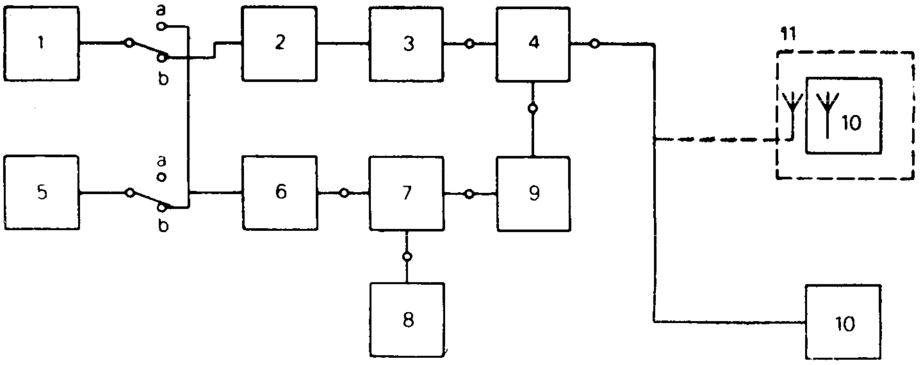
*a)* the level of an unwanted input signal that causes a wanted input signal, which is 3 dB in excess of the reference sensitivity ( selective calling ), to produce a calling probability equal to the standard calling probability, to

*b)* the reference sensitivity ( selective calling ).

### 12.2 *Method of measurement*

*Note.* — The value of the reference sensitivity ( selective calling ) determined in Sub-clause 8.3 is required for this measurement.

*a)* Connect the equipment as illustrated in Figure 3, with the switches in position b.



1 = encoder
2 = radio-frequency signal generator
3 = 60 dB step attenuator ( 1 dB steps )
4 = matching and combining network
5 = audio-frequency signal generator
6 = radio-frequency signal generator
7 = matching and combining network ( if required )
8 = radio-frequency signal generator ( if required )
9 = 60 dB step attenuator ( 1 dB steps )
10 = receiver-decoder
11 = radio-frequency coupling device ( if required )

*Notes. 1.* — The connections represented by the switches in position a are only for the test described in Sub-clause 15.2.

2. — The output signals of all generators should be reduced to zero unless otherwise indicated in the method of measurement.

FIG. 3. — General test arrangement for receiver-decoder characteristics.

*b)* Modulate the radio-frequency signal generator (2) with the SCTS.

*c)* In the absence of the unwanted signal, apply a signal from the radio-frequency signal generator (2) at the standard input-signal frequency so that the level at the input of the receiver.decoder is 3 dB in excess of the reference sensitivity ( selective calling ) determined in Sub-clause 8.3. Record this value.

*d)* Adjust the radio-frequency signal generator (6) and the audio-frequency signal generator (5) in order to produce the standard unwanted signal.

*Note.* — If 400 Hz is present in the encoded signal, and if the unwanted signal is modulated with 400 Hz, use some other frequency between 300 Hz and 500 Hz to modulate the unwanted signal ( see Sub-clause 3.11 ).

*e)* Adjust the level of radio-frequency signal generator (6) to a high value [ e.g. 80 dB ($\mu$V)] and set its frequency to produce a spurious response. Record this frequency in megahertz and this level in dB ($\mu$V).

*Note.* — The method of measurement of spurious response immunity ( selective calling ) requires that the operator search for the frequencies of the unwanted signals which may degrade the output of the receiver ( e. g., signal-to-noise ratio, calling probability, error rate, or message acceptance rate ). When the receiver has an audio output, this is normally done by applying only the unwanted signal to the receiver at a high level. Then the frequency of the unwanted signal is slowly moved across the frequency band of interest, and the frequencies that produce a change in signal-to-noise ratio are noted. These frequencies are then used in the spurious response immunity ( selective calling ) method of measurement.

If the receiver-decoder does not have an audio output, other methods for making the search shall be used. One method of making the search is to use a sensitive detector ( e.g., a communications receiver tuned to the intermediate frequency of the receiver-decoder ) and a probe ( antenna ) which may also be tuned to the i. f. By placing the probe near the later stages of the i. f. amplifier, the activity of the i. f. amplifier can be monitored. When the above procedure is used, changes in the signal in the i. f. amplifier can be detected and the frequency of the unwanted signal noted.

*f)* Decrease the step attenuator (9) to a value which will produce a low calling probability ( e.g., less than 10% ).

*g)* Transmit the SCTS repeatedly and adjust the step attenuator (9) according to the following rules:

*h)* 1) Transmit the SCTS a maximum of three times, terminating the transmission sequence, however, if the receiver-decoder fails to recognize the signal any one of those times. Adjust the step attenuator (9), according to Step *h)*2) or *h)*3), whichever is appropriate.

2) If the receiver-decoder fails to recognize either the first, second or third SCTS, increase the attenuation of (9) by 2 dB, and repeatthe Step *h)*1).

3) If the receiver-decoder recognizes the three SCTSs, record the attenuation value in decibels, decrease the attenuation value by 1 dB, and proceed to Step *i)*1).

*i)* 1) Transmit the SCTS a maximum of three times, terminating the transmission sequence, however, if the receiver-decoder fails to recognize the signal any one of those times. Adjust the step attenuator (9) according to Step *i)*2) or *i)*3), whichever is appropriate.

2) If the receiver-decoder fails to recognize either the first, second, or third SCTS, increase the attenuation of (9) by 1 dB, record the new attenuation value in decibels, and repeat Step *i)*1).

3) If the receiver-decoder recognizes the three SCTSs, decrease the attenuation of (9) by 1 dB, record the new attenuation value in decibels, and continue the SCTS transmission procedure in Step *i)*1) until the total number of Step *i)*1) transmissions is 40.

*Notes 1.* — If the rules do not require an attenuator change after a transmission of the SCTS, do not record an attenuation value.

*2.* — In these measurements the SCTS is transmitted 40 times.

*3.* — A careful study of the example in Figure F 4, page 130, of Appendix F, is recommended to avoid the possibility of misunderstanding Steps *h*) and *i*).

*j)* Steps *e)* to *i)* may be repeated for other unwanted signal frequencies.

### 12.3 *Presentation of results*

*a)* Calculate the average of the attenuation values recorded in Steps *h)* and *i)* of Sub-clause 12.2.

*b)* The spurious response immunity (selective calling) in decibels is:

$$A - B - C - D - E$$

where:

- $A$ is the output level of the radio-frequency signal generator (6) recorded in Step *e*) of Sub-clause 9.2 in dB ( $\mu$V )
- $B$ is the loss of the combining network (7) in decibels
- $C$ is the loss of the combining network (4) in decibels
- $D$ is the average attenuation value calculated in Step *a*) of this sub-clause in decibels
- $E$ is the reference sensitivity ( selective calling ) in dB ( $\mu$V ) determined in Sub-clause 8.3

*c)* Record in a table the unwanted signal frequency and the spurious response immunity (selective calling) calculated in Step *b)* of this sub-clause.

*d)* Record the reference sensitivity (selective calling) in dB ($\mu$V), the standard input-signal frequency and the characteristics of the standard unwanted signal used. If 400 Hz is not used to modulate the unwanted signal, record the frequency used.

### 12.4 *Compliance test method*

*Note.* — The value of the reference sensitivity (selective calling) determined in Sub-clause 8.3 is required for this test.

*a)* Connect the equipment as illustrated in Figure 3, with switches in position b. Attenuators (3) and (9) are either not connected or are set to zero attenuation.

*b)* Modulate the radio-frequency signal generator (2) with the standard coded test signal (SCTS).

*c)* In the absence of the unwanted signal, apply a signal from the radio-frequency signal generator (2) at the standard input signal frequency so that the level at the input of the receiver-decoder is 3 dB in excess of the reference sensitivity (selective calling) determined in Sub-clause 8.3. Record this value.

*d)* Adjust the audio-frequency signal generator (5) to modulate the radio-frequency signal generator (6) with the standard modulation of the unwanted signal.

If 400 Hz is present in the encoded signal and if the unwanted signal is to be modulated (see Sub-clause 3.11), use a frequency between 300 and 500 Hz, other than 400 Hz to modulate the unwanted signal.

*e)* Set the frequency of radio-frequency generator (6) to produce a spurious response, and adjust its level to apply to the receiver the specified unwanted signal level. Record the frequency and the level of the unwanted signal.

*Note.* — The test of spurious response immunity (selective calling) requires that the operator search for the frequencies of the unwanted signals which may degrade the output of the receiver-decoder (e.g. signal to-noise ratio, calling probability, error ratios or message acceptance ratios). When the receiver has an audio output, this is normally done by applying only the unwanted signal to the receiver-decoder at a high level. Then the frequency of the unwanted signal is slowly moved across the frequency band of interest and the frequencies that produce a change in the signal-to-noise ratio are noted. These frequencies are then used in the spurious response immunity (selective calling) test.

If the receiver-decoder does not have an audio output, other methods for making the search should be used. One method of making the search is to use a sensitive detector (e.g. communication receiver tuned to the intermediate frequency of the receiver-decoder) and a pickup (antenna) which may also be tuned to the intermediate frequency. By placing the pickup near the later stages of the intermediate frequency amplifier, the activity of this amplifier can be monitored. When the above procedure is used, changes in the signal in the intermediate frequency amplifier can be detected and the frequency of the unwanted signal noted.

*f)* Transmit the SCTS 33 times. If the receiver-decoder fails to recognize seven or more SCTS's, record that the receiver-decoder does not comply with the spurious response immunity (selective calling) specification; otherwise record that it does comply.

*Note.* — The test may be stopped after seven SCTS's have failed to be recognized.

*g)* Steps *e)* and *f )* may be repeated for other unwanted signal frequencies.

## 13. Intermodulation immunity ( selective calling )

### 13.1 *Definition*

The ability of the receiver-decoder to prevent two unwanted signals which have a specific frequency relationship to the wanted signal frequency (see Appendix D) from degrading the desired response at the output of the receiver-decoder.

It is the ratio, expressed in decibels, of:

*a)* the level of one of two equal-level unwanted input signals that cause a wanted input signal, which is 3 dB in excess of the reference sensitivity (selective calling), to produce a calling probability equal to the standard calling probability, to

*b)* the reference sensitivity (selective calling).

### 13.2 *Method of measurement*

*Notes 1.* — The value of the reference sensitivity ( selective calling ) determined in Sub-clause 8.3 is required for this measurement.

*2.* — A measuring error may result from intermodulation between generators, generator noise, or receiver desensitization. See Appendices A and B for precautions regarding the signal generators.

*a)* Connect the equipment as illustrated in Figure 3, with the switches in position b.

*b)* Modulate the radio-frequency signal generator (2) by the SCTS.

*c)* In the absence of the unwanted signals, apply a signal from the radio-frequency signal generator (2) at the standard input-signal frequency so that level at the input of the receiver-decoder is 3 dB in excess of the reference sensitivity (selective calling) determined in Sub-clause 8.3. Record this value.

*d)* Choose a pair of frequencies $f_n$ and $f_r$ that may produce an intermodulation response ( see Appendix D).

*e)* Adjust the unmodulated radio-frequency signal generator (8) to frequency $f_n$ and adjust the signal level to a high value, for example, 80 dB ($\mu$V). Record this level.

*f)* Apply the standard unwanted signal at the frequency $f_r$ from the radio-frequency signal generator (6) at the same level as in Step *e).*

*Note.* — If 400 Hz is present in the encoded signal, and if the unwanted signal is modulated with 400 Hz, use some other frequency between 300 Hz and 500 Hz to modulate the unwanted signal ( see Sub-clause 3.11 ).

*g)* Decrease the step attenuator (9) to a value which will produce a low calling probability (e.g., less than 10%).

*h)* Transmit the SCTS repeatedly and adjust the step attenuator (9) according to the following rules:

*i)* 1) Transmit the SCTS a maximum of three times, terminating the transmission sequence, however, if the receiver-decoder fails to recognize the signal any one of those times. Adjust the step attenuator (9), according to Step *i)*2) or *i)*3), whichever is appropriate.

2) If the receiver-decoder fails to recognize either the first, second or third SCTS, increase the attenuation of (9) by 2 dB, and repeat Step *i)*1).

3) If the receiver-decoder recognizes the three SCTSs, record the attenuation value in decibels decrease the attenuation of (9) by 1dB, record the new attenuation value in decibels, and proceed to Step *j)*1).

*j)* 1) Transmit the SCTS a maximum of three times, terminating the transmission sequence, however, if the receiver-decoder fails to recognize the signal any one of those times. Adjust the step attenuator (9) according to Step *j)*2) or *j)*3), whichever is appropriate.

2) If the receiver-decoder fails to recognize either the first, second, or third SCTS, stop the SCTS, increase the attenuation of (9) by 1dB, record the new attenuation value in decibels, and repeat Step *j)*1).

3) If the receiver-decoder recognizes the three SCTSs, decrease the attenuation of (9) by 1 dB, record the new attenuation value in decibels, and continue the SCTS transmission procedure in Step *j)*1) until the total number of Step *j)*1) transmissions is 40.

*Notes 1.* — If the rules do not require an attenuator change after a transmission of SCTS, do not record an attenuation value.

*2.* — In this step the SCTS is transmitted 40 times.

*3.* — A careful study of the example in Figure F4, page 130, of Appendix F is recommended to avoid the possibility of misunderstanding Steps *i)* and *j)*.

*k)* Steps *d)* to *j)* may be repeated for other unwanted signal frequencies.

### 13.3 *Presentation of results*

*a)* Calculate the average of the attenuation values recorded in Steps *i)* and *j)* of Sub-clause 13.2.

*b)* The intermodulation immunity (selective calling), in decibels, is:

$$A - B - C - D - E$$

where:

$A$ is the output level of the radio-frequency signal generator (8) ( the output level of the radio-frequency signal generator (6) is at the same level ) recorded in Step *e )* of Sub-clause 13.2 in dB ( $\mu$V )

$B$ is the loss of the combining network (7) in decibels

$C$ is the loss of the combining network (4) in decibels

$D$ is the average of the attenuation values calculated in Step a) of this sub-clause, in decibels

$E$ is the reference sensitivity ( selective calling ) in dB ( $\mu$V ) determined in Sub-clause 8.3

*c)* Record in a table the values of the departure from the standard input signal frequency of the unwanted signal frequencies and the intermodulation immunity (selective calling) calculated in Step *b)*.

*d)* Record the reference sensitivity (selective calling) in dB ($\mu$V), the standard input-signal frequency and the characteristics of the standard unwanted signal used. If 400 Hz is not used to modulate the unwanted signal, record the frequency used.

### 13.4 *Compliance test method*

*Notes 1.* — The value of the reference sensitivity (selective calling) determined in Sub-clause 8.3 is required for this test.

*2.* — A measuring error may result from intermodulation between generators, generator noise or receiver desensitization. See Appendices A and B for precautions regarding the signal generators.

*a)* Connect the equipment as illustrated in Figure 3, with switches in position b. Attenuators (3) and (9) are either not connected or are set to zero attenuation.

*b)* Modulate the radio-frequency signal generator (2) with the standard coded test signal (SCTS).

*c)* In the absence of the unwanted signal, apply a signal from the radio-frequency signal generator (2) at the standard input signal frequency so that the level at the input of the receiver-decoder is 3 dB in excess of the reference sensitivity (selective calling) determined in Sub-clause 8.3. Record this value.

*d)* Choose a pair of frequencies, $f_n$ and $f_r$, that may produce an intermodulation response (see Appendix D). Record these frequencies.

*e)* Adjust the unmodulated radio-frequency generator (8) to frequency $f_n$ and adjust the signal level to apply the specified unwanted signal level to the receiver-decoder input. Record the frequency and the level of the unwanted signal.

*f)* Apply the standard unwanted signal at the frequency $f_r$ from radio-frequency signal generator (6) at the same level as in Step *e)*.

If 400 Hz is present in the encoded signal and if the unwanted signal is to be modulated (see Sub-clause 3.11), use a frequency between 300 and 500 Hz, other than 400 Hz, to modulate the unwanted signal.

*g)* Transmit the SCTS 33 times. If the receiver-decoder fails to recognize seven or more SCTS's, record that the receiver-decoder does not comply with the intermodulation immunity (selective calling) specification; otherwise record that it does comply.

*Note.* — The test may be stopped after seven SCTS's have failed to be recognized.

*h)* Steps *d)* through *g)* may be repeated for other unwanted signal frequencies.

## 14. Sensitivity reduction under multipath propagation conditions ( selective calling )

Variations of amplitude and phase of a radio-frequency signal are created by multipath reflections in the propagation medium whenever the transmitting or receiving antennas are in motion. These signal variations are a function of both the antenna velocity and the frequency of the desired radio-frequency signal.

Variations of signal amplitude, due to motion, follow a Rayleigh distribution in limited areas where the direct signal is missing. They may, therefore, be simulated by modulating the desired radio-frequency signal.

### 14.1 *Definition*

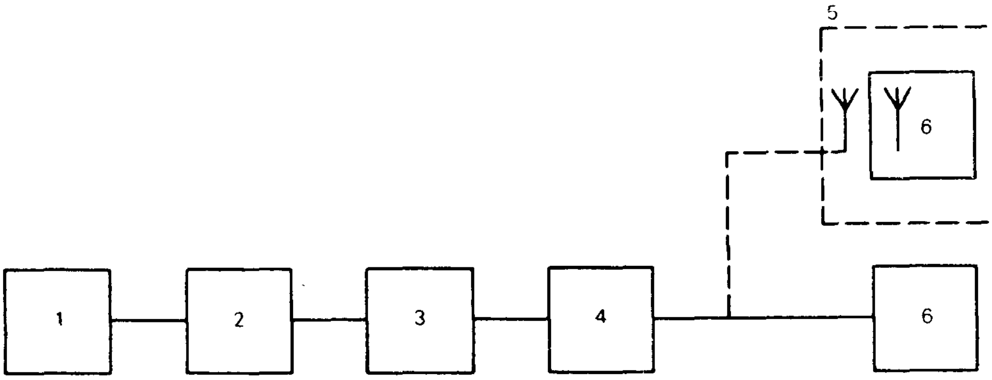
The ratio, expressed in decibels, of:

*a)* the r.m.s. value of a Rayleigh faded input signal level that is required to maintain the standard calling probability, to

*b)* the reference sensitivity (selective calling).

### 14.2 *Method of measurement*

*a)* Connect the equipment as illustrated in Figure 4 (see Appendix C for details of the Rayleigh fading simulator).



1 = encoder
2 = radio-frequency signal generator
3 = Rayleigh fading simulator
4 = step attenuator ( 1 dB steps )
5 = radio-frequency coupling device ( if required )
6 = receiver-decoder

FIG. 4. — Arrangement for measuring receiver-decoder sensitivity reduction under multipath propagation conditions.

*b)* Modulate the radio-frequency signal generator (2) with the SCTS.

*c)* Apply the output of the radio-frequency signal generator (2) to the Rayleigh fading simulator (3) at the level specified by the manufacturer of the fading simulator.

*d)* Adjust the Rayleigh fading simulator to the non-fading setting and adjust the level so that it is equal to the r.m.s. output value that the simulator would have at other velocities. Proceed to Step *f)*.

*e)* Adjust the velocity of the simulator to a specified velocity.

*f)* Increase the step attenuator (4) to a value which will produce a low calling probability (e.g., less than 10 %).

*g)* Transmit the SCTS repeatedly and adjust the step attenuator (4) according to the following rules:

*h)* 1) Transmit the SCTS a maximum of three times, terminating the transmission sequence, however, if the receiver-decoder fails to recognize the signal any one of those times. Adjust the step attenuator (4), according to Step *h)*2) or *h)*3, whichever is appropriate.

2) If the receiver-decoder fails to recognize either the first, second or third SCTS, decrease the attenuation of (4) by 2 dB, and repeat Step *h)*1).

3) If the receiver-decoder recognizes the three SCTSs, record the attenuation value in decibels, increase the attenuation of (4) by 1 dB, record the new attenuation value in decibels, and proceed to Step *i)*1).

*i)* 1) Transmit the SCTS a maximum of three times, terminating the transmission sequence, however, if the receiver-decoder fails to recognize the signal any one of those times. Adjust the step attenuator (4) according to Step *i)*2) or *i)*3), whichever is appropriate.

2) If the receiver-decoder fails to recognize either the first, second, or third SCTS, decrease the attenuation of (4) by 1 dB, record the new attenuation value in decibels and repeat Step *i)*1).

3) If the receiver-decoder recognizes the three SCTSs, increase the attenuation of (4) by 1 dB, record the new attenuation value in decibels, and continue the SCTS transmission procedure in Step *i)*1) until the total number of Step *i)*1) transmissions is 40.

*Notes 1.* — If the rules do not require an attenuator change after a transmission of the SCTS, do not record an attenuation value.

2. — In this step the SCTS is transmitted 40 times.

3. — A careful study of the example in Figure F4, page 130, of Appendix F is recommended to avoid the possibility of misunderstanding Steps *h)* and *i)*.

*j)* Repeat Steps *e)* to *i)* with the Rayleigh fading simulator (3) adjusted for 100, 50, 20, 10, 5, 2 and 1 km/h (see Appendix C).

14.3 *Presentation of results*

*a)* Calculate the average of the attenuation values recorded in Steps *h)* and *i)* of Sub-clause 14.2, with the Rayleigh fading simulator set to the non-fading position as in Step *d)* of Sub-clause 14.2.

*b)* Calculate the average of the attenuation values recorded in Steps *h)* and *i)* of Sub-clause 14.2, with the Rayleigh fading simulator adjusted for a velocity specified in Step *e)* of Sub-clause 14.2.

*c)* The sensitivity reduction under multipath propagation conditions (selective calling) in decibels is:

$$A - B$$

where:

$A$ is the average of the attenuation values calculated in Step *a)* in decibels
$B$ is the average of the attenuation values calculated in Step *b)* in decibels

*d)* Record in a table the velocities and the sensitivity reduction under multipath propagation conditions (selective calling).

*e)* Record the standard input-signal frequency.

14.4 *Compliance test method*

*Note.* — The value of the reference sensitivity (selective calling) determined in sub-clause 8.3 is required for this measurement.

*a)* Connect the equipment as illustrated in Figure 4 (see Appendix C for details of the Rayleigh fading simulator).

*b)* Modulate the radio-frequency signal generator (2) with the standard coded test signal (SCTS).

*c)* Apply the output of the radio-frequency signal generator (2) to the Rayleigh fading simulator (3) at the level specified by the manufacturer of the fading simulator.

*d)* Adjust the attenuator (4) to produce the specified signal level at the receiver input.

*e)* Adjust the velocity control of the simulator to 100 km/h for mobile applications or 10 km/h for portable applications.

*f)* Transmit SCTS 33 times. If the receiver-decoder fails to recognize seven or more SCTS's, record that the receiver-decoder does not comply with the sensitivity reduction under multipath propagation conditions (selective calling) specification; otherwise record that it does comply.

*Note.* — The test may be stopped after seven SCTS's have failed to be recognized.

*g)* Repeat Steps *e)* and *f)* with the Rayleigh fading simulator successively adjusted to 50, 20 and 10 km/h for mobile applications or 5, 2 and 1 km/h for portable applications.

## 15. Protection from radio-frequency intermodulation false operation ( selective calling )

### 15.1 *Definition*

The ability of the receiver-decoder to prevent two unwanted signals (one of which is modulated by the SCTS) having a spceific frequency relationship to the wanted signal frequency, from causing unwanted responses at the output of the receiver-decoder due to intermodulation (see Appendix D).

It is the ratio, expressed in decibels, of:

*a)* the level of the modulated unwanted signal that produces the standard calling probability, to

*b)* reference sensitivity (selective calling).

*Note.* — This method of measurement provides the two-signal intermodulation characteristic. For specific modulation processes, the modulating signal may have to be inverted.

### 15.2 *Method of measurement*

*Notes 1.* — The value of the reference sensitivity ( selective calling ) determined in Sub-clause 8.3 is required for this measurement.

2. — A measuring error may result from intermodulation between generators, generator noise, or receiver desensitization. See Appendices A and B for precautions regarding the signal generators.

*a)* Connect the equipment as illustrated in Figure 3, with the switches in position a.

*b)* Choose a pair of frequencies $f_n$ and $f_r$ that may produce an intermodulation response (see Appendix D). Record these frequencies.

*c)* Adjust the unmodulated radio-frequency signal generator (6) to frequency $f_r$ modulated with the SCTS and adjust the signal level to a high value, for example 80 dB ($\mu$V). Record this level.

*d)* Apply the unwanted unmodulated input signal of frequency $f_r$ from the output of the radio-frequency signal generator (8) to the combining network (7) at the same level as in Step *c)*.

*e)* Increase the step attenuator (9) to a value which will produce a low calling probability (e.g., less than 10%).

*f)* Transmit the SCTS repeatedly and adjust the step attenuator (9) according to the following rules:

*g)* 1) Transmit the SCTS a maximum of three times, terminating the transmission sequence, however, if the receiver-decoder fails to recognize the signal any one of those times. Adjust the step attenuator (9), according to Step *g)*2) or *g)*3), whichever is appropriate.

2) If the receiver-decoder fails to recognize either the first, second, or third SCTS, decrease the attenuation of (9) by 2 dB, and repeat Step *g)*1).

3) If the receiver-decoder recognizes the three SCTSs, record the attenuation value in decibels, increase the attenuation of (9) by 1 dB, record the new attenuation value in decibels, and proceed to Step *h)*1).

*h)* 1) Transmit the SCTS a maximum of three times, terminating the transmission sequence, however, if the receiver-decoder fails to recognize the signal any one of those times. Adjust the step attenuator (9), according to Step *h)*2) or *h)*3), whichever is appropriate.

2) If the receiver-decoder fails to recognize either the first, second, or third SCTS, decrease the attenuation of (9) by 1 dB, record the new attenuation value in decibels, and repeat Step *h)*1).

3) If the receiver-decoder recognizes the three SCTSs, increase the attenuation of (9) by 1 dB, record the new attenuation value in decibels, and continue the SCTS transmission procedure in Step *h)*1) until the total number of Step *h)*1) transmissions is 40.

*Notes.* *1.* — If the rules do not require an attenuator change after a transmission of the SCTS, do not record an attenuation value.

*2.* — In this step the SCTS is transmitted 40 times.

*3.* — A careful study of the example in Figure F 3, page 129, of Appendix F is recommended to avoid the possibility of misunderstanding Steps *g)* and *h)*.

*i)* Steps *b)* to *h)* may be repeated for other unwanted signal frequencies.

### 15.3 *Presentation of results*

*a)* Calculate the average of the attenuation values recorded in Steps *g)* and *h)* of Sub-clause 15.2.

*b)* The protection from radio-frequency intermodulation false operation (selective calling) in decibels is:

$$A-B-C-D-E$$

where:

$A$ is the output level of the radio-frequency signal generator (6) ( the output of the radio-frequency signal generator (8) is set at the same level ) recorded in Step *c)* of Sub-clause 15.2 in dB (µV)

$B$ is the loss of the combining network (7) in decibels

$C$ is the loss of the combining network (4) in decibels

$D$ is the average of the attenuation values calculated in Step *a)* of this Sub-clause, in decibels

$E$ is the reference sensitivity (selective calling) in dB (µV) determined in Sub-clause 8.3

*c)* Record in a table the values of the departure from the standard input-signal frequency of the unwanted signals and the protection from radio-frequency intermodulation false operation (selective calling) in Step *b)*.

*d)* Record the reference sensitivity (selective calling) in dB (µV) and the standard input-signal frequency.

## 16. False responses due to noise ( selective calling )

Receiver noise can cause the decoder to produce false calling responses in the absence of selective calling signals.

### 16.1 *Definition*

The mean time between false calling responses ($M$) is defined as the average time between consecutive false calling responses.

For the purpose of this measurement, this time is estimated by observing the time required to produce eight false calling responses and dividing it by eight.

### 16.2 *Method of measurement*

*Notes.* *1.* — Five per cent of the measurements will require more than 13 times the mean time ($M$) of the equipment (see Appendix G), if the required measurement time is too long to be practical, this measurement should not be specified.

2. — This test is applicable only to receivers in which the squelch can be disabled, thus allowing receiver noise to reach the decoder.

*a)* Terminate the input terminals of the receiver as specified by the manufacturer and, with no input signal applied to the receiver, deactivate the receiver squelch.

*b)* Adjust receiver gain and volume control, if fitted for normal decoder operation, in accordance with the manufacturer's instructions.

*c)* Monitor the operation of the decoder until eight false operations have occurred. Record the total time interval ($H$) in hours.

16.3 *Presentation af results*

Calculate $M$, using:

$$M = \frac{H}{8} \text{ (hours)}$$

16.4 *Compliance test method*

This test is applicable only to receivers in which the squelch can be disabled thus allowing receiver noise to reach the decoder.

*a)* For receiver-decoders with antenna terminals, terminate the input terminals of the receiver as specified by the manufacturer. Receiver-decoders with an integral antenna should be shielded. With no input signal applied to the receiver-decoder, deactivate the receiver squelch.

*b)* Adjust the receiver gain and volume control, if fitted for normal decoder operation in accordance with the manufacturer's instructions.

*c)* Test the receiver-decoder for a maximum period of 8.67 times $M$. Note the number of false calling responses $F$ in the elapsed time $T$.

$M$ is the specified mean time between consecutive false calling responses
$T$ is in the same units as $M$
$F$ is the number of false calling responses

Record that the receiver-decoder does comply with the false responses due to noise (selective calling) specification if:

1) at the end of the test period, $F$ is 8 or less,
or

2) at any time during the test period, $[T]$ is greater than $F+3$. The test is then terminated.

Record that the receiver-decoder does not comply with the false responses due to noise (selective calling) specification if:

1) at any time during the test period, $F$ is greater than 8. The test is then terminated,
or

2) at any time during the test period, $F$ is greater than $T+3$. The test is then terminated.

*Example:*

An equipment with $M = 1.6$ h will comply with the specification if 8 or less false calling responses are detected in 13.87 h (8.67 × 1.6) or if only two false calling responses have been detected after 8 h (5 × 1.6).

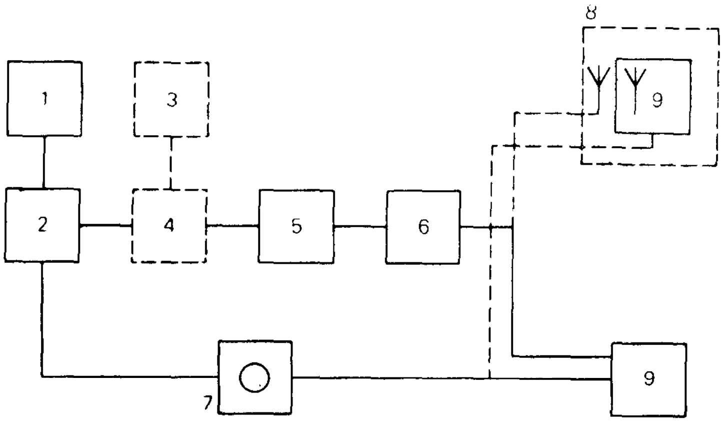
## 17. Signalling attack time (selective calling)

### 17.1 *Definition*

The elapsed time from the instant when the radio-frequency input-signal modulated by the standard coded test signal is applied at the receiver until the receiver-decoder successfully responds. If the response is an audio output, then the signalling attack time (selective calling) is measured when the audio output reaches 50% of the steady-state value.

### 17.2 *Method of measurement*

*a)* Connect the equipment as illustrated in Figure 5.



1 = controller (programme)
2 = encoder
3 = audio-frequency signal generator (if required)
4 = matching and combining network (if required)
5 = radio-frequency signal generator
6 = attenuator
7 = oscilloscope
8 = radio-frequency coupling device (if required)
9 = receiver-decoder

FIG. 5. — Measuring arrangement.

*b)* Modulate the radio-frequency signal generator (5) with the SCTS.

*c)* Adjust the radio-frequency signal generator (5) to the standard input-signal frequency and to produce a level 30 dB above reference sensitivity (selective calling) at the receiver input terminals.

*d)* Display the encoder voltage on one trace of a double-beam oscilloscope and display the decoder alarm indicating signals on the other beam.

*e)* Measure the time interval from the instant when the coded signal voltage applied to the radio-frequency signal generator exceeds 50% of its maximum level until the alarm circuit output has reached 50% of its maximum amplitude.

[illegible]

been detected after 8 h ($5 \times 1.6$).

## 18. Recovery time ( selective calling )

### 18.1 *Definition*

The minimum time interval that is needed between two successive encoded calling sequences to ensure that the decoder will respond correctly to the second sequence.

This characteristic can be observed only when the decoder automatically resets.

### 18.2 *Method of measurement*

*a)* Connect the equipment specified by the manufacturer as illustrated in Figure 5, page 51.

*b)* Modulate the radio-frequency signal generator (5) with the SCTS.

*c)* Adjust the radio-frequency signal generator (5) to the standard input-signal frequency and to produce a level 30 dB above reference sensitivity ( selective calling).

*d)* Arrange for the interval between two successive SCTSs to be variable from zero to at least twice the recovery time stated by the manufacturer.

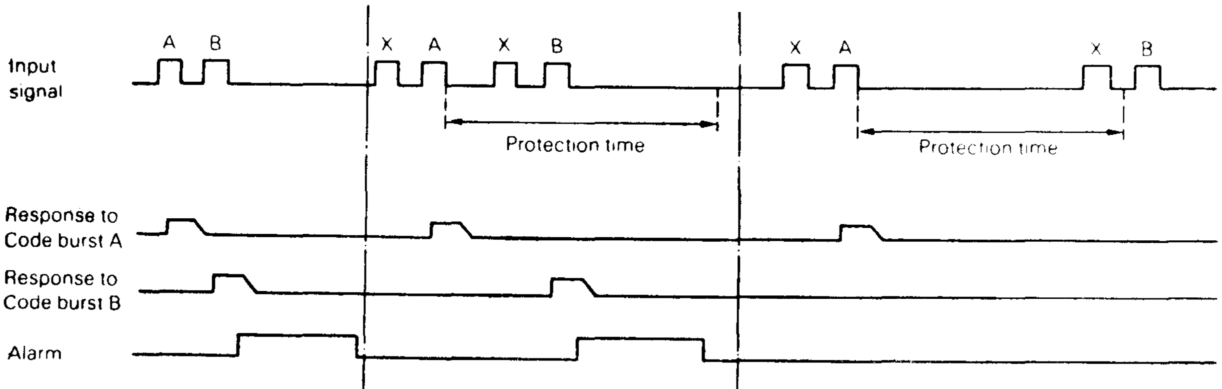
*e)* With the time interval set for zero, transmit the two SCTSs repeatedly and observe whether the second SCTS is successfully decoded. After each transmission series, adjust the interval according to the following rules:

- if the receiver-decoder fails to decode the signal, increase the interval by 20% of the value of the recovery time stated by the manufacturer;
- if the receiver-decoder successfully decodes the signal, do not change the interval until there have been four consecutive successes. Then record this value of the interval. This is the recovery time (selective calling).

## 19. Required protection time ( selective calling )

### 19.1 *Definition*

The maximum time during which a partially operated decoder requires protection from other coded signals containing the complementary part of the necessary code (see Figure 6).



Case a Correct alarm response to correctly coded signal

Case b False alarm response to two incorrect but complementary signals, where the second is transmitted within the required protection time

Case c No alarm response to two incorrect signals as in Case b, but when the interval between the complementary parts just exceeds the required protection time

FIG. 6. — Protection time.

19.2 *Method of measurement*

*a)* Connect the equipment as illustrated in Figure 3, page 35.

The encoder used to make the measurement shall incorporate a means to vary the time interval between transmission of the two parts of the SCTS.

*b)* Modulate the radio-frequency signal generator (2) with the SCTS.

*c)* Adjust the radio-frequency signal generator (2) to the standard input-signal frequency and to produce a level 30 dB above reference sensitivity (selective calling) at the receiver input terminals.

*d)* Arrange the encoder to initially send the first part of an SCTS and after an interval, adjustable up to recovery time, send the remaining part of the SCTS.

*e)* Increase the interval to a value which will produce a low calling probability (e.g. less than 10%).

*f)* Transmit the SCTS repeatedly and observe whether the signal is successfully decoded. After each transmission, adjust the interval according to the following rules:

— if the receiver-decoder (10) fails to decode the signal, decrease the interval by 20% of the value of protection time stated by the manufacturer;

— if the receiver-decoder (10) successfully decodes the signal, do not change the interval until there have been four consecutive successes. Record this value of time interval. This is the protection time (selective calling).

*Note.* — In individual-tone sequential system having more than two tones, it may be necessary to repeat this measurement with the time interval in different positions of the SCTS.

## 20. Signal-to-residual output-power ratio (selective calling)

This characteristic is only applicable to receivers and decoders employing continuous individual-tone selective calling signalling and having accessible audio-terminals.

20.1 *Definition*

The ratio, expressed in decibels, of:

*a)* the receiver output power when a signal modulated with 1 000 Hz plus the continuous selective calling tone is applied to its input, to

*b)* the receiver output power when a signal modulated only by the continuous selective calling tone is applied to its input.

20.2 *Method of measurement*

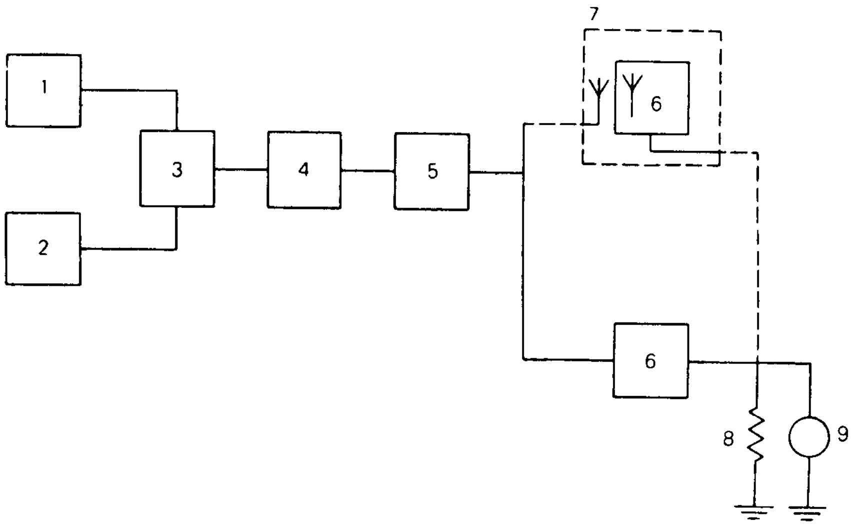
*a)* Connect the equipment as illustrated in Figure 7.

*b)* Connect the audio-frequency test load and an audio-frequency voltmeter to the output of the receiver.

*c)* Apply a standard input signal modulated with 1 000 Hz and the continuous selective calling tone at a level 30 dB above the level which produces 12 dB SINAD to the input of the receiver.

The composite modulation should be adjusted in accordance with the manufacturer's instructions.

*d)* Adjust the receiver volume control to produce the reference output power at the test load.



1 = 1 000 Hz generator
2 = audio-frequency signal generator
3 = matching and combining network
4 = radio-frequency signal generator
5 = attenuator
6 = receiver-decoder
7 = radio-frequency coupling device
8 = audio-frequency test load
9 = audio-frequency voltmeter

FIG. 7. — Measuring arrangement for signal-to-residual output-power ratio ( selective calling ).

*e)* Remove the standard 1 kHz modulation but not the continuous individual-tone modulation and record the reduction, in decibels, of the power dissipated in the audio-frequency load.

## 21. Impulsive-noise tolerance ( selective calling )

### 21.1 *Definition*

The ability of a receiver to prevent impulsive-noise from degrading the desired response at the output of the receiver.

It is expressed as a ratio of:

*a)* The median level of spectrum amplitude of the impulsive-noise that causes a wanted signal, which is 3 dB in excess of the reference sensitivity (selective calling), to produce a calling probability equal to the standard calling probability, to

*b)* the reference sensitivity (selective calling).

### 21.2 *Method of measurement*

*Notes. 1.* — The value of the reference sensitivity determined in Sub-clause 8.3 is required for this measurement.

*2.* — For information on the characteristics and calibration of a random impulse generator, see Appendix M.

*a)* Calibrate the random impulse generator in accordance with Sub-clause M3 of Appendix M and record the minimum attenuation median spectrum amplitude $S$ and the minimum attenuation value $M$. Increase the attenuation to a high value.

*b)* Connect the equipment as illustrated in Figure 3, page 35, and connect the random impulse generator to the input of matching and combining network (7) in place or radio-frequency generator (6) (see Appendix A).

*c)* Modulate the radio-frequency signal generator (2) with the SCTS.

*d)* In the absence of the impulsive-noise, apply a signal from the radio-frequency generator (2) at the standard input frequency so that the level at the input of the receiver-decoder is 3 dB in excess of the reference sensitivity (selective calling) determined in Sub-clause 8.3. Record this value in dB ($\mu$V).

*e)* Adjust the random impulse generator to the following settings:

— a frequency 100 kHz below the standard input frequency,

— an average pulse repetition rate of 100 impulses per second,

— a pulse duration of 0.2 $\mu$s,

— a standard deviation of amplitude of 6 dB,

— a 10 Hz cut-off frequency of the low-pass filter,

— a minimum spectrum amplitude.

*Note.* — The random impulse generator settings simulate the radio-frequency noise produced by city traffic that would impinge on the antenna of a nearby mobile land station. The above settings of the random impulse generator are not applicable to other environments.

*f)* Decrease the random impulse generator attenuator and decrease the step attenuator (9) to a value which will produce a low calling probability (e.g. less than 10%). Record the value $A$ of the random impulse generator.

*g)* Transmit the SCTS repeatedly and adjust the step attenuator (9) according to the following rules.

*h)* 1) Transmit the SCTS a maximum of three times, terminating the transmission sequence, however, if the receiver-decoder fails to recognize the signal any one of those times. Adjust the step attenuator (9) according to Step *h)* 2) or *h)* 3), whichever is appropriate.

2) If the receiver-decoder fails to recognize either the first, second or third SCTS, increase the attenuation of (9) by 2 dB, and repeat Step *h)* 1).

3) If the receiver-decoder recognizes the first, second and third SCTS, record the attenuation value in dB, decrease the attenuation of (9) by 1 dB, record the new attenuation value in decibels, and proceed to Step *j)* 1).

*j)* 1) Transmit the SCTS a maximum of three times, terminating the transmission sequence, however, if the receiver-decoder fails to recognize the signal any one of these times. Adjust the step attenuator (9) according to Step *j)* 2) or *j)* 3, whichever is appropriate.

2) If the receiver-decoder fails to recognize either the first, second, or third SCTS, increase the attenuation of (9) by 1 dB, record the new attenuation value in decibels, and repeat Step *j)* 1).

3) If the receiver-decoder recognizes the three SCTSs, decrease the attenuation of (9) by 1 dB, record the new attenuation value in decibels, and continue the SCTS transmission procedure in Step *j)* 1) until the total number of Step *j)* 1) transmission is 40.

*Note.* — A careful study of the example in Figure F4, page 130, of Appendix F is recommended to avoid the possibility of misunderstanding Steps *h)* and *j)*.

21.3 *Presentation of results*

*a)* Calculate D, the average of the attenuation values recorded in Steps *h)* and *j)* of Sub-clause 21.2.

*b)* The impulsive-noise tolerance is:

$$S-D-A+M-B-C-E \qquad \text{dB}\left[\frac{\mu\text{V/MHz}}{\mu\text{V}}\right]$$

where:

$S$ is the minimum attenuation median spectrum amplitude recorded in Step *a)* of Sub-clause 21.2
$D$ is the attenuation value calculated in Step *a)*
$A$ is the attenuation value recorded in Step *f)* of Sub-clause 21.2
$M$ is the minimum attenuation value recorded in Step *a)* of Sub-clause 21.2
$B$ is the loss of the combining network (7) in decibels
$C$ is the loss of the combining network (4) in decibels
$E$ is the reference sensitivity (selective calling) in dB (μV)

*c)* Record the impulsive-noise tolerance (selective calling), the standard input signal frequency, the reference sensitivity (selective calling), and the settings of the random impulse generator.

## SECTION FOUR — MEASUREMENTS OF RECEIVER-DECODER RADIO-FREQUENCY PARAMETERS (DATA)

### 22. Supplementary definitions for receiver-decoder radio-frequency measurements (data)

The definitions listed in Clause 22 apply to the methods of measurement described in Clauses 23 to 30. The definitions listed in Clause 3 apply to the methods of measurement described in Clauses 7 to 21.

22.1 *Binary digit*; *abbrev.: bit* (IEV 702-05-03*)

A member of a set of two elements commonly used to represent information.

22.2 *Bit error ratio*

The number of erroneous bits received, divided by the total number of bits transmitted.

22.3 *Bit rate*

The number of bits transmitted per unit of time, expressed in bit/s, kbit/s or Mbit/s.

22.4 *Bit stream*

A continuous series of bits.

22.5 *Character* (IEV 721-03-09†)

A member of a set of elements agreed upon to be used for organization, representation or control of information.

*Note.* — Characters may be letters, digits, punctuation marks or other symbols and, by extension, function controls such as space shift, carriage return or line feed contained in a message.

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*International Electrotechnical Vocabulary (IEV) [IEC Publication 50]. IEV Chapter 702, Oscillations, signals and related devices, is at present under consideration.

†IEV Chapter 721, Telegraphy, facsimile and data communication, is being printed.

22.6 *Character string*

A character or sequence of characters.

22.7 *Comparator (data)*

*Comparator (bit stream or character string)*

A device capable of:

— storing a reference sequence of bits or characters,

— counting the number of bits or characters that are transmitted,

— comparing the bits or characters received with the reference sequence of bits or characters, and

— counting the number of correctly received bits or characters.

*Comparator (message)*

A device or person capable of:

— storing a reference message,

— counting the number of times a message is transmitted,

— comparing the message received with the reference message, and

— counting the number of correctly received messages.

22.8 *Data* (IEV 721-01-02)

Information represented in a manner suitable for automatic processing.

22.9 *Decoder*

A device, which may be in the receiver, that translates the demodulated signal into the intended output signal.

22.10 *Encoder (data)*

A device which translates a group of input signals into a unique group of output signals suitable for transmission.

*Note.* — Examples of functions that may be involved are:

— addition of synchronization bits,

— addition of error control bits,

— parallel/serial conversion,

— amplitude and phase shaping.

22.11 *Erroneous bit, character or message*

Any decoded bit, character or message that is not the same as the transmitted bit, character or message.

22.12 *Error*

Failure to decode correctly the intended transmitted bit, character or message.

*Note.* — Another type of error is the reception of data in the absence of any intended transmission (false reception). The mean time between two successive false receptions is generally so high that a measurement would be impractical; this parameter is estimated by calculation.

22.13 *Message* (IEV 721-09-01)

A group of characters and function control sequences which is transferred as an entity from a transmitter to a receiver, where the arrangement of the characters is determined at the transmitter.

22.14 *Message format*

Description of the elements and their arrangement in a message.

*Note.* — The arrangement may include among other items, synchronization bits, address bits, text, flag bits and additional bits for error correction and/or detection.

Synchronization bits: additional bits which are provided only for the purpose of synchronization.
Address: information that identifies the address or identifies the sending unit.

Function: information that identifies which of a plurality of responses is to be executed.
Text: information (e.g., character string).

Error control bits: bits which are provided solely for the purpose of error correction and/or detection.

22.15 *Peak envelope amplitude*

In amplitude modulation, the amplitude of one radio-frequency oscillation at the crest of the envelope of the modulated wave.

22.16 *Port*

A place of access to a device or network where energy, representing data, may be supplied or withdrawn, or where the device or network variables may be observed or measured.

22.17 *Reference error ratio*

The following reference ratios apply for an equipment measured with the standard coded test signal (data).

*a)* Reference error ratio (data)

The ratio is the number of erroneous bits, characters or messages to the total number of bits, characters or messages transmitted.

*b)* The reference error ratios are:

| | |
|---|---|
| Reference error ratio (bit stream) | 0·01 or 1% |
| Reference error ratio (character string) | 0·01 or 1% |
| Reference error ratio (message) | 0·2 or 20% |

22.18 *Standard base band test signals*

For the purpose of the measurements described in this standard the following qualifications apply:

*a)* Reference sequence of bits

A binary sequence pattern of 511 bits which are generated in a pseudo-random order.

*Note.* — For details concerning the generation of the pseudo-random binary sequence (PRBS) pattern, see CCITT Fascicle VIII. 1, Recommendation V 52.

*b)* Reference sequence of characters

A character sequence pattern comprising all elements of a specified character set arranged in a specified pseudo-random order.

*c)* Reference sequence of messages

A sequence of three transmissions of the specified message.

22.19 *Standard coded test signal (data): SCTS ( data )*

The radio-frequency signal applied to a data receiver-decoder that simulates the output of a transmitter which is modulated by one of the following standard base band test signals:

- — the reference sequence of bits, or
- — the reference sequence of characters, or
- — the reference sequence of messages,

at the bit rate defined in the data equipment specification.

All parameter tolerances (e.g. rise times, tone frequencies, phase-shift angles), shall be small enough to ensure that the results are not significantly influenced. In addition to any other parameters, the equipment specification shall define the appropriate values for:

- — the modulation depth of double-sideband modulation, or
- — the frequency/phase deviation of angle modulation, or
- — the amplitude relationship to the carrier of single-sideband, full, reduced or variable carrier modulation,
- — the frequency relationship to the carrier of single-sideband, full, reduced or variable carrier modulation.

### 22.20 *Standard train of standard coded test signal (bit stream or character string)*

*Note.* — The length of the standard trains have been chosen in order to achieve a dispersion of ±1 dB for the measurement of reference sensitivity and of ±2 dB for all other measurements.

For all measurements and compliance tests, except sensitivity reduction under multipath propagation conditions (bit stream or character string), the standard trains are:

| | |
|---|---|
| For bit stream | 2 556 bits of SCTS |
| For character string | 2 556 characters of SCTS |

*Note.* — For the measurements in this standard, the required reliability is obtained if the transmission is stopped after 26 bit or character errors are detected.

For the measurement of sensitivity reduction under multipath propagation conditions (bit stream or character string), the standard trains are:

For bit stream:

2 556 bits of SCTS

or

$$\frac{43\ 200 \times (\text{bit rate})}{\text{km/h} \times \text{MHz}}$$

whichever is greater

For character string:

2 556 characters of SCTS

or

$$\frac{43\ 200 \times (\text{character rate}) \times (\text{bits per character})}{\text{km/h} \times \text{MHz}}$$

whichever is greater.

For ease of measurement, this length may be rounded off to the smallest integer multiple of the reference sequence of bits or of characters that exceed the above values.

*Note.* — For the measurements in this standard, the transmission may be stopped after 0·01 × bits plus bit error or 00·1 × character plus 1 character error are detected.

22.21 *Standard unwanted signal (data)*

The standard unwanted signal for measuring spurious response immunity and intermodulation immunity is not modulated.

The standard unwanted signal for measuring adjacent radio-frequency signal selectivity or co-channel interference rejection is continuously modulated with a binary sequence pattern of 32 767 bits which is generated in a pseudo-random order. The modulation is identical with the modulation characteristics of the system transmitter.

22.22 *Telegraphy* (IEV 721-01-06)

A form of telecommunication in which the transmitted information is intended to be recorded on arrival as a graphic document; the transmitted information may sometimes be presented in alternative form or may be stored for subsequent use.

*Notes. 1.* — A graphic document records information in a permanent form and is capable of being filed and consulted; for example it may take the form of written or printed matter or of a fixed image.

*2.* — This is the definition given in the International Telecommunication Convention (Nairobi 1982).

*3.* — Telegraphy does not include television and videography.

22.23 *Test data source (message)*

A device that will:

1) generate the message in the form of electrical signals,

2) repeat the message for a specified number of times and at specified intervals.

## 23. Reference sensitivity (data)

23.1 *Definition*

The radio-frequency level of the standard coded test signal (data), at a specified frequency, which will result in the reference error ratio (data).

23.2 *Method of measurement for bit stream or character string*

*a)* Connect the equipment as illustrated in Figure 3 with the switches in position b. Test equipment items (1) and (2) and a comparator are required (see Sub-clause 22.7).

*b)* Adjust the frequency of the radio-frequency signal generator (2) to one of the specified nominal frequencies.

*c)* Using encoder (1) modulate radio-frequency signal generator (2) with the standard train of coded test signal (bit stream or character string) to generate the standard coded test signal (SCTS) (bit stream or character string) (see Sub-clauses 22.18, 22.19 and 22.20).

*d)* Adjust the level of the input signal to the receiver-decoder to the value of the reference sensitivity (bit stream or character string) stated in the equipment specification.

*e)* Transmit the standard train of SCTS's (see Sub-clause 22.20).

*f)* Calculate and note the error ratio.

*g)* If the error ratio equals the reference error ratio (bit stream or character string), terminate the measurement. Record the radio-frequency signal level as the reference sensitivity (bit stream or character string) and proceed to Step *b)* of Sub-clause 23.3.

If the error ratio is less than reference error ratio (bit stream or character string), decrease the input signal level to the receiver-decoder by 0.5 dB.

If the error ratio is greater than the reference error ratio (bit stream or character string), increase the input signal level to the receiver-decoder by 0.5 dB.

*h)* Repeat Steps *e)* through *g)* until two consecutive values of error ratio have been obtained, which bracket the reference error ratio (bit stream or character string). Record the input signal level, V, in dB ($\mu$V) that corresponds to the error ratio which is just greater than the reference error ratio (bit stream or character string).

23.3 *Presentation of results for bit stream or character string*

*a)* Calculate the reference sensitivity (bit stream or character string), $S$, as follows:

$$S = V + 0.25 \text{ in dB } (\mu\text{V})$$

where:

$V$ is the value of input signal level to the receiver-decoder recorded in Step *h)* of Sub-clause 23.2.

*b)* Record the input signal arrangement used, characteristics of the SCTS (bit stream or character string) and the reference sensitivity (bit stream or character string).

23.4 *Method of measurement for message*

*a)* Connect the equipment as illustrated in Figure 3 with the switches in position b. Test equipment items (1), (2) and (3) are required (see Sub-clause 22.7).

*b)* Adjust the frequency of the radio-frequency signal generator (2) to one of the specified nominal frequencies.

*c)* Apply to the attenuator (3) a signal having the standard input-signal frequency and at a level of approximately 60 dB ($\mu$V). Record this level as A.

*d)* Using encoder (1) modulate the radio-frequency signal generator (2) with the reference sequence of messages to generate the standard coded test signal (SCTS) (message) (see Sub-clauses 22.18 and 22.19).

*e)* Adjust step attenuator (3) to a value which will produce a high error ratio (e.g. 50% or greater).

*f)* 1) Transmit the SCTS a maximum of three times, terminating the transmission sequence if the receiver-decoder fails to recognize the SCTS any one of those times. Adjust the step attenuator (3) according to Step *f)* 2) or *f)* 3), whichever is appropriate.

2) If the receiver-decoder fails to recognize either the first, second or third SCTS, decrease the attenuation of (3) by 2 dB and repeat Step *f)* 1).

3) If the receiver-decoder recognizes the three SCTS's record the attenuation value in decibels, increase the attenuation of (3) by 1 dB, record the new attenuation value in decibels, and proceed to Step *g)* 1).

*g)* 1) Transmit the SCTS a maximum of three times, terminating the transmission sequence if the receiver-decoder fails to recognize the SCTS any one of those times. Adjust the step attenuator (3) according to Step *g)* 2) or *g)*3), whichever is appropriate.

2) If the receiver-decoder fails to recognize either the first, second or third SCTS, decrease the attenuation of (3) by 1 dB, record the new attenuation value in decibels, and repeat Step *g)*1). See Step *h)*.

3) If the receiver-decoder recognizes the three SCTS's, increase the attenuation of (3) by 1 dB, record the new attenuation value in decibels, and repeat Step *g)*1). See Step *h)*.

*h)* Continue Steps *g)*1), *g)*2) and *g)*3) until attenuator values have been recorded 20 times.

23.5 *Presentation of results for message*

*a)* Calculate the average of the attenuation values recorded in decibels in steps *f)*3), *g)*2) and *g)*3) of Sub-clause 23.4.

*b)* The reference sensitivity (message) is:

$$A - B \text{ dB } (\mu\text{V})$$

where:
$A$ is the value recorded in Step *c)* of Sub-clause 23.4.
$B$ is the average of the attenuation values calculated in Step *a)* in decibels.

*c)* Record the input signal arrangement used, characteristics of the SCTS (message) and reference sensitivity (message).

23.6 *Compliance test method — Sensitivity (data)*

*a)* Connect the equipment as illustrated in Figure 3 with the switches in position b, using test equipment items (1) and (2) and a comparator (see 22.7).

*b)* Adjust the frequency of the radio-frequency signal generator (2) to one of the specified nominal frequencies.

*c)* Using encoder (1), modulate radio-frequency signal generator (2) with the standard train of coded test signal (data) or with the specified message to generate the standard coded test signal (data) (SCTS) (see 22.14, 22.18, 22.19 and 22.20).

*d)* Adjust the level of the input signal to the receiver-decoder to the specified value of reference sensitivity (data).

*e)* Transmit the standard train of SCTS's for bit stream or character string (see 22.20), or 18 specified messages.

*f)* If there are 25 or less errors for bit stream or character string, or three or less errors for message, record that the receiver-decoder does comply with the sensitivity (data) specification, otherwise record that it does not comply.

*g)* Record the input signal arrangement used, characteristics of the SCTS (data) and the specified sensitivity (data).

## 24. Acceptable radio-frequency displacement (data)

24.1 *Definition*

The ability of a receiver-decoder to minimize the degradation of the desired response of the receiver-decoder when the input signal frequency is displaced from the specified nominal frequency.

It is the smaller of the two possible radio-frequency displacements that causes an input signal which is 6 dB in excess of the reference sensitivity (data) to produce an error ratio equal to the reference error ratio (data).

*Note.* — Radio-frequency displacement is an absolute value and an increase in the displacement is to move the radio-frequency away from the nominal frequency.

24.2 *Method of measurement for bit stream and character string*

*Note.* — The value of the reference sensitivity (bit stream or character string) determined in Sub-clause 23.3 is required for this measurement.

*a)* Connect the equipment as illustrated in Figure 3 with the switches in position b. Test equipment items (1) and (2) and a comparator are required (see Sub-clause 22.7).

*b)* Adjust the frequency of the radio-frequency signal generator (2) to one of the specified nominal frequencies.

*c)* Using encoder (1) modulate radio-frequency signal generator (2) with the standard train of coded test signal (bit stream or character string) to generate the standard coded test signal (SCTS) (bit stream or character string) (see Sub-clauses 22.18, 22.19 and 22.20).

*d)* Adjust the level of the input signal to the receiver-decoder to a value 6 dB in excess of the reference sensitivity (bit stream and character string) determined in Sub-clause 23.3.

*e)* Adjust the input signal frequency displacement to the value of the acceptable radio-frequency displacement (bit stream and character string) stated in the equipment specification.

*f)* Transmit the standard train of SCTS's (see Sub-clause 22.20).

*g)* Calculate and note the error ratio.

*h)* If the error ratio equals the reference error ratio (bit stream and character string,) terminate the measurement. Record the radio-frequency displacement $F$, as the acceptable radio-frequency displacement (bit stream and character string), and proceed to Step *b)* of Sub-clause 24.3.

If the error ratio is less than the reference error ratio (bit stream and character string), increase the frequency displacement by 100 Hz.
If the error ratio is greater than the reference error ratio (bit stream and character string), decrease the frequency displacement by 100 Hz.

*i)* Repeat Steps *f)* through *h)* until two consecutive values of error ratio have been obtained which bracket the reference error ratio (bit stream and character string). Record the frequency displacement, $D$, that corresponds to the error ratio which is just greater than the reference error ratio (bit stream and character string).

*j)* Repeat Steps *e)* through *i)* for the frequency displacement on the other side of the specified nominal frequency.

24.3 *Presentation of results for bit stream and character string*

*a)* Calculate the upper and lower radio-frequency displacement, $F$, as follows:

$$F = D - 50 \text{ Hz}$$

where:
$D$ is the magnitude of the frequency displacement recorded in Step *i*) or *j*) of Sub-clause 24.2.

*b)* The acceptable radio-frequency displacement is the smallest value of $F$.

*c)* Record the input signal arrangement used, characteristics of the SCTS (bit stream and character string) and the acceptable radio-frequency displacement (bit stream and character string).

*Note.* — This method of measurement is suitable for making measurements at other levels than the 6 dB increase per Step of *d*)Sub-clause 24.2.

24.4 *Method of measurement for message*

*Note.* — The value of the reference sensitivity (message) determined in Sub-clause 23.5 is required for this measurement.

*a)* Connect the equipment as illustrated in Figure 3 with the switches in position b. Test equipment items (1) and (2) and a comparator are required (see Sub-clause 22.7).

*b)* Adjust the frequency of the radio-frequency signal generator (2) to one of the specified nominal frequencies.

*c)* Using encoder (1) modulate radio-frequency signal generator (2) with the reference sequence of message to generator the standard coded test signal (SCTS) (message) (see Sub-clauses 22.18 and 22.19).

*d)* Adjust the level of the input signal to the receiver-decoder to a value 6 dB in excess of the reference sensitivity (message) determined in Sub-clause 23.5.

*e)* Increase the input signal frequency displacement to a value which will produce a high error ratio (e.g., 50% or greater).

*f)* 1) Transmit the SCTS a maximum of three times, terminating the transmission sequence if the receiver-decoder fails to recognize the SCTS any one of those times. Adjust the input signal frequency displacement according to Step *f)* 2) or *f)* 3), whichever is appropriate.

2) If the receiver-decoder fails to recognize the first, second or third SCTS, decrease the input signal frequency displacement by 200 Hz and repeat Step *f)* 1).

3) If the receiver-decoder recognizes the three SCTS's, record the input signal frequency, increase the input signal frequency displacement by 100 Hz, record the new frequency, and proceed to Step *g)* 1).

*g)* 1) Transmit the SCTS a maximum of three times, terminating the transmission sequence if the receiver-decoder fails to recognize the SCTS any one of those times. Adjust the input signal frequency displacement according to Step *g)* 2) or *g)* 3, whichever is appropriate.

2) If the receiver-decoder fails to recognize either the first, second or third SCTS, decrease the input signal frequency displacement by 100 Hz, record the new frequency and repeat Step *g)* 1). See Step *h)*.

3) If the receiver-decoder recognizes the three SCTS's increase the input signal frequency displacement by 100 Hz, record the new frequency and repeat Step *g)* 1). See Step *h)*.

*h)* Continue Steps *g)* 1), *g)* 2) and *g)* 3) until frequency displacement values have been recorded 40 times.

*i)* Repeat Steps *e)* through *h)* for the frequency displacement on the other side of the specified nominal frequency.

24.5 *Presentation of results for message*

*a)* Calculate the average of the upper and lower radio-frequency displacements recorded in Steps *f)* 3), *g)* 2) and *g)* 3) of Sub-clause 23.4. Record these values.

*b)* Record the acceptable radio-frequency displacement (message) as the smaller of the values found in Step *a)*.

*c)* Record the input signal arrangement used, characteristics of the SCTS (message) and the reference sensitivity (message).

*Note.* — This method of measurement is suitable for making measurements at other levels than the 6 dB increase per Step *d)*.

### 24.6 *Compliance test method — Acceptable radio-frequency displacement (data)*

*Note.* — The value of the reference sensitivity (data) determined in 23.3 or 23.5 is required for this measurement.

*a)* Connect the equipment as illustrated in Figure 3 with the switches in position b, using test equipment items (1) and (2) and a comparator (see 22.7).

*b)* Adjust the frequency of the radio-frequency signal generator (2) to one of the specified nominal frequencies.

*c)* Using encoder (1), modulate radio-frequency signal generator (2) with the standard train of coded test signal (data) or with the specified message to generate the standard coded test signal (data) (SCTS) (see 22.14, 22.18, 22.19 and 22.20).

*d)* Adjust the level of the input signal to the receiver-decoder to a value 6 dB in excess of the reference sensitivity (data) determined in 23.3 or 23.5.

*e)* Adjust the input signal frequency displacement to the upper specified value of the acceptable radio-frequency displacement (data).

*f)* Transmit the standard train of SCTS's for bit stream or character string (see 22.20), or 33 specified messages.

*g)* If there are 25 or less errors for bit stream or character string, or six or less errors for message, record that for this displacement the receiver-decoder does comply with the upper specified acceptable radio-frequency displacement (data) specification, othewise record that it does not comply.

*h)* Repeat steps *e)* through *g)* for the frequency displacement on the lower side of the specified nominal frequency.

*i)* If it was recorded in step *g)* that the receiver-decoder does comply for both frequency displacements, then record that it does comply with the acceptable radio-frequency displacement (data) specification, otherwise record that it does not comply.

*j)* Record the input signal arrangement used, characteristics of the SCTS (data) and the specified value of the acceptable radio-frequency displacement (data).

## 25. Adjacent radio-frequency signal selectivity (data)

### 25.1 *Definition*

The ability of the receiver-decoder to minimize the degrading effect of an unwanted adjacent signal on the desired response at the output of the receiver-decoder. It is the ratio, expressed in decibels of:

*a)* the level of an unwanted input signal that causes a wanted input signal, which is 3 dB in excess of the reference sensitivity (data), to produce an error ratio equal to the reference error ratio (data)

to

*b)* the reference sensitivity (data).

### 25.2 *Method of measurement for bit stream and character string*

*Note* — The value of the reference sensitivity (bit stream and character string) determined in Sub-clause 23.3 is required for this measurement.

*a)* Connect the equipment as illustrated in Figure 3 with the switches in position b. Test equipment items (1), (2), (4), (5) and (6) and a comparator are required (see Sub-clause 22.7). Item (5) is replaced with an unwanted signal encoder.

*b)* Adjust the frequency of the radio-frequency signal generator (2) to one of the specified nominal frequencies.

*c)* Using encoder (1) modulate radio-frequency signal generator (2) with the standard train of coded test signal (bit stream or character string) to generate the standard coded test signal (SCTS) (bit stream or character string) (see Sub-clauses 22.18, 22.19 and 22.20).

*d)* In the absence of the unwanted signal, adjust the wanted signal level at the input of the matching and combining network (4) to be 3 decibels in excess of the reference sensitivity (bit stream and character string) determined in Sub-clause 23.3 plus the loss of the matching and combining network (4). Record this value as $R$ in dB ($\mu$V).

*e)* Using encoder (5) modulate radio-frequency generator (6) with the standard unwanted signal (data) to generate the unwanted signal at the upper (lower) specified frequency of the adjacent unwanted signal (see Sub-clause 22.21).

Adjust the level to the input of the matching and combining network (4) to equal the reference sensitivity (bit stream and character string) multiplied by the ratio of the adjacent radio-frequency signal selectivity (bit stream and character string), stated in the equipment specification plus the loss of the matching and combining network (4).

*f)* Transmit the standard train of SCTS's (see Sub-clause 22.20).

*g)* Calculate and note the error ratio.

*h)* If the error ratio equals the reference error ratio (bit stream or character string), terminate the measurement. Record the radio-frequency signal level, $G$, in dB ($\mu$V), and proceed to Step *b)* of Sub-clause 25.3.

If the error ratio is less than the reference error ratio (bit stream or character string), increase the unwanted input signal level to the receiver-decoder by 0.5 dB.

If the error ratio is greater than the reference error ratio (bit stream or character string), decrease the unwanted input signal level to the receiver-decoder by 0.5 dB.

*i)* Repeat Steps *e)* through *h)* until two consecutive values of error ratio have been obtained which bracket the reference error ratio (bit stream or character string). Record the unwanted input signal level, in dB ($\mu$V) that corresponds to the error ratio which is just greater than the reference error ratio (bit stream or character string).

*j)* Repeat Steps *e)* through *i)* for the lower specified frequency of the adjacent unwanted signal.

*Note.* — This method of measurement is suitable for making measurements at other than the specified unwanted signal frequency.

### 25.3 *Presentation of results for bit stream and character string*

*a)* Calculate the level of the unwanted radio-frequency, $G$, as follows:

$$G = U - 0.25 - L \text{ in dB } (\mu\text{V})$$

where:

$D$ is the unwanted input signal level to the receiver decoder recorded in Steps *i)* or *j)* of Sub-clause 25.2

$L$ is the loss of matching and combining network (4)

*b)* Calculate the upper and the lower adjacent radio-frequency signal selectivities, $S$, as follows:

$$S = G - R \text{ in decibels}$$

where:

$G$ is the value recorded in Step *h)* of Sub-clause 25.2 or in Step *a*) of Sub-clause 25.3

$R$ is the reference sensitivity (bit stream and character string) plus the loss of the matching and combining network (4) recorded in Step *d)* of Sub-clause 25.2.

*c)* Record the adjacent radio-frequency signal selectivity (bit stream and character string) as the smaller of the values of $S$ calculated above.

*d)* Record the input signal arrangement used, the characteristics of the SCTS ( bit stream or character string ), the characteristics of the unwanted signal, the frequencies of the specified unwanted adjacent signals and the reference sensitivity ( bit stream and character string ).

25.4 *Method of measurement for message*

*Note.* — The value of the reference sensitivity ( message ) determined in Sub-clause 24.5 is required for this measurement.

*a)* Connect the equipment as illustrated in Figure 3 with the switches in position b. Test equipment items (1), (2), (4), (5), (6) and (9) and a comparator are required ( *see* Sub-clause 22.7 ). Item (5) is replaced with an unwanted signal encoder.

*b)* Adjust the frequency of the radio-frequency signal generator (2) to one of the specified nominal frequencies.

*c)* Using encoder (1), modulate radio-frequency signal generator (2) with the reference sequence of messages to generate the standard coded test signal (SCTS) (message) ( *see* Sub-clauses 22.18 and 22.19).

*d)* In the absence of the unwanted signal, adjust the signal level at the input of the matching and combining network (4) to be 3 dB in excess of the reference sensitivity (message) determined in Sub-clause 23.5, plus the loss of the matching and combining network (4). Record this value as $R$ in dB ($\mu$V).

*e)* Using encoder (5) modulate radio-frequency generator (6) with the standard unwanted signal (data) to generate the unwanted signal at the upper (lower) specified frequency of the adjacent unwanted signal (*see* Sub-clause 22.21). Apply a high level signal (e.g. 100 dB ($\mu$V) to the attenuator (9). Record this value, $A$, in dB ($\mu$V).

*f)* Adjust the step attenuator (9) to a value which will produce a high error ratio (e.g.50% or greater).

*g)* 1) Transmit the SCTS a maximum of three times, terminating the transmission sequence if the receiver-decoder fails to recognize the SCTS any one of those times. Adjust the step attenuator (9) according to Step *g)*2) or *g)*3,) whichever is appropriate.

2) If the receiver-decoder fails to recognize either the first, second or third SCTS, increase the attenuation of (9) by 2 dB and repeat Steps *g)*1).

3) If the receiver-decoder recognizes the three SCTS's, record the attenuation value in decibels, decrease the attenuation of (9) by 1 dB, record the new attenuation value in decibels, and proceed to Step *h)* 1).

*h)* 1) Transmit the SCTS a maximum of the three times, terminating the transmission sequence if the receiver-decoder fails to recognize the SCTS any one of those times. Adjust the step attenuator (9) according to Step *h)*2) or *h)*3), whichever is appropriate.

2) If the receiver-decoder fails to recognize either the first, second or third SCTS, increase the attenuation of (9) by 1 dB, record the new attenuation value in decibels, and repeat Step *h)*1). See Step *i)*.

3) If the receiver-decoder recognizes the three SCTS's, decrease the attenuation of (9) by 1 dB, record the new attenuation value in decibels, and repeat Step *h)*1). See Step *i)*.

*i)* Continure Steps *h)*1), *h)*2) and *h)*3) until attenuator values have been recorded 40 times.

*j)* Repeat Steps *e)* through *i)* for the lower specified frequency of the adjacent unwanted signal.

25.5 *Presentation of results for messaage*

*a)* Calculate the average of the attenuation values recorded in decibels in Steps *g)*3), *h)*2) and *h)*3) of Sub-clause 25.4 for the upper frequency of the adjacent unwanted signal.

*b)* Calculate the average of the attenuation values recorded in decibels in Steps *g)*3), *h)*2) and *h)*3) of Sub-clause 25.4 for the lower frequency of the adjacent unwanted signal.

*c)* Calculate the upper and lower adjacent radio-frequency signal selectivity, S, as follows:

$$S = A - B - C - R \text{ in decibels}$$

where:

$A$ is the value recorded in dB ($\mu$V) in Step *e*) of Sub-clause 25.4

$B$ is the average of the attenuation values calculated in Step *a*) in decibels

$C$ is the loss of the matching and combining network (4) in decibels

$R$ is the reference sensitivity (message, plus the loss of the matching and combining network (4) recorded in Step *d*) of Sub-clause 25.4

*d)* Record the adjacent radio-frequency signal selectivity (message) as the smaller of the values of $S$ calculated above.

*e)* Record the input signal arrangement used, the characteristics of the SCTS (message), the characteristics of the unwanted signal, and the frequencies of the specified unwanted adjacent signals and reference sensitivity (message).

25.6 *Compliance test method — Adjacent radio-frequency signal selectivity (data)*

*Note.* — The value of the reference sensitivity (data) determined in 23.3 or 23.5 is required for this measurement.

*a)* Connect the equipment as illustrated in Figure 3 with the switches in position b. Test equipment items (1), (2), (4), (5), (6) and a comparator are required (22.7). Item (5) is replaced with an unwanted signal encoder.

*b)* Adjust the frequency of the radio-frequency signal generator (2) to one of the specified nominal frequencies.

*c)* Using encoder (1), modulate radio-frequency signal generator (2) with the standard train of coded test signal (data) or with the specified message to generate the standard test signal (data) (SCTS) (see 22.14, 22.18, 22.19 and 22.20).

*d)* Adjust the wanted signal level at the input of the matching and combining network (4) to be 3 dB in excess of the reference sensitivity (data) determined in 23.3 or 23.5, plus the loss of the matching and combining network (4). Record this value in dB ($\mu$V).

*e)* Using encoder (5), modulate radio-frequency generator (6) with the standard unwanted signal (data) to generate the unwanted signal at the upper specified adjacent frequency (see 22.21).

*f)* Adjust the unwanted signal level at the input of the matching and combining network (4) to equal the reference sensitivity (data) determined in 23.3 or 23.5, increased by the specified value of the adjacent radio-frequency signal selectivity (data) plus the loss of the matching and combining network (4).

*g)* Transmit the standard train of SCTS's for bit stream or character string ( see 22.20), or 33 specified messages.

*h)* If there are 25 or less errors for bit stream or character string, or six or less errors for message, record that for the upper specified frequency the receiver-decoder does comply with the adjacent radio-frequency signal selectivity (data) specification.

*i)* Repeat steps *e)* through *h)* for the lower specified adjacent frequency.

*j)* If it was recorded in step *h)* that the receiver-decoder does comply for both specified frequencies, then record that it does comply with the adjacent radio-frequency signal selectivity (data) specification, otherwise record that it does not comply.

*k)* Record the input signal arrangement used, characteristics of the SCTS (data), the reference sensitivity (data) and the specified adjacent radio-frequency signal selectivity (data).

## 26. Co-channel interference rejection (data)

Co-channel interference rejection (data) is a special case of adjacent radio-frequency signal selectivity (data). It is measured using the method of measurement given in Clause 25 with the frequency of the standard unwanted signal (data) the same as the wanted signal.

## 27. Adjacent-channel selectivity (data)

When mobile radio services use discrete channel spacings, the value of adjacent radio-frequency signal selectivity (data) measured for a signal spacing equal to the discrete channel spacing may be quoted as the value of the adjacent-channel selectivity (data). Adjacent channel selectivity (data) is measured using the method of measurement given in Clause 25, with the frequency of the standard unwanted signal displaced one channel space.

## 28. Spurious response immunity (data)

### 28.1 *Definition*

The ability of the receiver-decoder to prevent a single unwanted spurious signal from degrading the desired response. It is the ratio, expressed in decibels, of:

*a)* the level of an unwanted input signal that causes a wanted input signal, which is 3 dB in excess of the reference sensitivity (data), to produce an error ratio equal to the reference error ratio (data),

to

*b)* the reference sensitivity (data).

### 28.2 *Method of measurement for bit stream and character string*

*Note.* — The value of the reference sensitivity (bit stream and character string) determined in Sub-clause 23.3 is required for this measurement.

*a)* Connect the equipment as illustrated in Figure 3 with the switches in position b. Test equipment items (1), (2), (4) and (6) and a comparrtor are required (see Sub-clause 22.7).

*b)* Adjust the frequency of the radio-frequency signal generator (2) to one of the specified nominal frequencies.

*c)* Using encoder (1) modulate radio-frequency signal generator (2) with the standard train of coded test signal (bit stream or character string) to generate the standard coded test signal (SCTS) (bit stream or character string) (see Sub-clauses 22.18, 22.19 and 22.20).

*d)* In the absence of the unwanted signal, adjust the signal level at the input of the matching and combining network (4) to be 3 dB in excess of the reference sensitivity (bit stream and character string) determined in Sub-clause 23.3, plus the loss of the matching and combining network (4). Record this value as $R$ in dB ($\mu$V).

*e)* Adjust radio-frequency generator (6) to a frequency that may degrade the response of the receiver-decoder. Note the unwanted signal frequency (see Sub-clause 22.21).

Adjust the level to the input of the matching and combining network (4) to equal the reference sensitivity (bit stream and character string), multiplied by the ratio of the spurious response immunity (bit stream and character string), stated in the equipment specification, plus the loss of the matching and combining network (4).

*Note.* — The method of measurement of spurious response immunity requires that the operator search for the frequencies of the unwanted signals which may degrade the output of the receiver (e.g., signal-to-noise ratio, or error ratio). When the receiver has an audio output, this is normally done by applying only the unwanted signal to the receiver at a high level. Then the frequency of the unwanted signal is slowly moved across the frequency band of interest and the frequencies that produce a change in the signal-to-noise ratio are noted. These frequencies are then used in the spurious response immunity method of measurement.

If the receiver-decoder does not have an audio output, other methods for making the search should be used. One method of making the search is to use a sensitive detector (e.g., a communication receiver tuned to the intermediate frequency of the receiver-decoder) and a pickup (antenna) which may also be tuned to the intermediate frequency. By placing the pickup near the later stages of the intermediate frequency amplifier the activity of this amplifier can be monitored. When the above procedure is used, changes in the signal in the intermediate frequency amplifier can be detected and the frequency of the unwanted signal noted.

*f)* Transmit the standard train of SCTS's ( see Sub-clause 22.20).

*g)* Calculate and note the error ratio.

*h)* If the error ratio equals the reference error ratio (bit stream or character string), terminate the measurement. Record the radio-frequency signal level, $G$, in dB ($\mu$V), and proceed to Step *b)* of Sub-clause 28.3.

If the error ratio is less than the reference error ratio (bit stream or character string), increase the unwanted input signal level to the receiver-decoder by 0.5 dB.

If the error ratio is greater than the reference error ratio (bit stream or character string), decrease the unwanted input signal level to the receiver-decoder by 0.5 dB.

*i)* Repeat Steps *e)* through *h)* until two consecutive values of error ratio have been obtained which bracket the reference error ratio (bit stream or character string). Record the unwanted input signal level, $U$ in dB ($\mu$V), that corresponds to the error ratio which is just greater than the reference error ratio (bit stream or character string).

*j)* Repeat Steps *d)* through *i)* for other unwanted signal frequencies that may degrade the response of the receiver-decoder.

### 28.3 *Presentation of results for bit stream and character string*

*a)* Calculate the radio-frequency level $G$, as follows:

$$G = U - 0.25 \quad \text{in dB } (\mu\text{V})$$

where:

$U$ is the unwanted input signal level to the receiver decoder recorded in Step *i)* or *j)* of Sub-clause 28.2.

*b)* Calculate the spurious response immunity, $S$, for each of the unwanted signals as follows:

$$S = G - R \quad \text{in decibels}$$

where:

$G$ is the value recorded in Step *h)* of Sub-clause 28.2 or in Step *a)* of Sub-clause 25.3

$R$ is the reference sensitivity (bit stream and character string) plus the loss of the matching and combining network (4) recorded in Step *d)* of Sub-clause 28.2.

*c)* Record the spurious response immunity (bit stream and character string) as the smaller of the values of $S$ calculated above.

*d)* Record the input signal arrangement used, the characteristics of the SCTS (bit stream and character string), the characteristics of the unwanted signal, the frequencies of the specified unwanted adjacent signals and the reference sensitivity (bit stream and character string).

28.4 *Method of measurement for message*

*Note.* — The value of the reference sensitivity (message) determined in Sub-clause 23.5 is required for this measurement.

*a)* Connect the equipment as illustrated in Figure 3 with the switches in position b. Test equipment items (1), (2), (4), (6) and (9) and a comparator are required (see Sub-clause 22.7).

*b)* Adjust the frequency of the radio-frequency signal generator (2) to one of the specified nominal frequencies.

*c)* Using encoder (1) modulate radio-frequency signal generator (2) with the reference sequence of messages to generate the standard coded test signal (SCTS) (message) (see Sub-clauses 22.18 and 22.19).

*d)* In the absence of the unwanted signal adjust the signal level at the input of the matching and combining network (4) to 3 dB in excess of the reference sensitivity (message) determined in Sub-clause 23.5, plus the loss of the matching and combining network (4). Record this value as $R$ in dB ($\mu$V).

*e)* Adjust radio-frequency generator (6) to a frequency that may degrade the response of the receiver-decoder and apply a high level signal [e.g., 100 dB ($\mu$V) ] to the attenuator (9) (see Sub-clause 22.21). Record this value in dB ($\mu$V ) as $A$. Record this frequency.

*Note.* — The method of measurement of spurious response immunity requires that the operator search for the frequencies of unwanted signals which may degrade the output of the receiver (e.g., signal-to-noise ratio, or error ratio). When the receiver has an audio output, this is normally done by applying only the unwanted signal to the receiver at a high level. Then the frequency of the unwanted signal is slowly moved across the frequency band of interest and the frequencies that produce a change in the signal-to-noise ratio are noted. These frequencies are then used in the spurious response immunity method of measurement.

If the receiver-decoder does not have an audio output, other methods for making the search should be used. One method of making the search is to use a sensitive detector (for example, a communication receiver tuned to the intermediate frequency of the receiver-decoder) and a pickup (antenna) which may also be tuned to the intermediate frequency. By placing the pickup near the later stages of the intermediate frequency amplifier the activity of this amplifier can be monitored. When the above procedure is used, changes in the signal in the intermediate frequency amplifier can be detected and the frequency of the unwanted signal noted.

*f)* Adjust the step attenuator (9) to a value which will produce a high error ratio (e.g.,50% or greater).

*g)* 1) Transmit tne SCTS a maximum of three times, terminating the transmission sequence if the receiver-decoder fails to recognize the SCTS any one of those times. Adjust the step attenuator (9) according to Step *g)*2) or *g)*3), whichever is appropriate.

2) If the receiver-decoder fails to recognize either the first, second or third SCTS, increase the attenuation of (9) by 2 dB and repeat Step *g)*1).

3) If the receiver-decoder recognizes the three SCTS's, record the attenuation value in decibels, decrease the attenuation of (9) by 1 dB, record the new attenuation value in decibels, and proceed to Step *h)* 1).

*h)* 1) Transmit the SCTS a maximum of three times, terminating the transmission sequence if the receiver-decoder fails to recognize the SCTS any one of those times. Adjust the step attenuator (9) according to Step *h)* 2) or *h)* 3), whichever is appropriate.

2) If the receiver-decoder fails to recognize either the first, second or third SCTS, increase the attenuation of (9) by 1 dB, record the new attenuation value in decibels, and repeat Step *h)* 1). See Step *i)*.

3) If the receiver-decoder recognizes the three SCTS's, decrease the attenuation of (9) by 1 dB, record the new attenuation value in decibels, and repeat Step *h)* 1). See Step *i)*.

*i)* Continue Steps *h)* 1), *h)* 2) and *h)* 3) until attenuator values have been recorded 40 times.

*j)* Repeat Steps *e)* through *i)* using other unwanted signal frequencies that may degrade the response of the receiver-decoder.

28.5 *Presentation of results for message*

*a)* Calculate the average of the attenuation values recorded in decibels in Steps *g)* 3), *h)* 2) and *h)* 3) of Sub-clause 28.4 for each of the unwanted signals.

*b)* Calculate the spurious response immunity (message), *S*, for each of the unwanted signals as follows:

$$S = A - B - C - R \text{ in decibels}$$

where:

$A$ is the value recorded in Step *e*) of Sub-clause 28.4

$B$ is the average of the attenuation values calculated in Step *a*) in decibels

$C$ is the loss of the matching and combining network (4), from the radio-frequency signal generator (6) to receiver input, in decibels

$R$ is the reference sensitivity (message) plus the loss of the matching and combining network (4) recorded in Step *d*) of Sub-clause 28.4

*c)* Record the spurious response immunity (message) as the smaller of the values of *S* calculated above.

*d)* Record the input signal arrangement used, the characteristics of the SCTS (message), the characteristics of the unwanted signal, the frequencies of the unwanted signals and the reference sensitivity (message).

28.6 *Compliance test method — Spurious response immunity (data)*

*Note.* — The value of the reference sensitivity (data) determined in 23.3 or 23.5 is required for this measurement.

*a)* Connect the equipment as illustrated in Figure 3 with the switches in position b, using test equipment items (1), (2), (4) and (6) and a comparator (see 22.7).

*b)* Adjust the frequency of the radio-frequency signal generator (2) to one of the specified nominal frequencies.

*c)* Using encoder (1), modulate radio-frequency signal generator (2) with the standard train of coded test signal ( data ) or with the specified message to generate the standard coded test signal (data) (STCS) (see 22.14, 22.18, 22.19 and 22.20).

*d)* Adjust the wanted signal level at the input of the matching and combining network (4) to be 3 dB in excess of the reference sensitivity ( data ) determined in 23.3 or 23.5, plus the loss of the matching and combining network (4). Record this value in dB ($\mu$V).

*e)* Adjust radio-frequency generator (6) to a frequency that may degrade the response of the receiver-decoder. Note the unwanted signal frequency ( see 22.21 ).

*Note.* — The method of measurement of spurious response immunity requires that the operator search for the frequencies of the unwanted signals which may degrade the output of the receiver ( e.g. signal-to-noise ratio or error ratio ). When the receiver has an audio output, this is normally done by applying only the unwanted signal to the receiver at a high level. Then the frequency of the unwanted signal is slowly moved accross the frequency band of interest and the frequencies that produce a change in the signal-to-noise ratio are noted. These frquencies are then used in the spurious response immunity method of measurement.

If the receiver-decoder does not have an audio output, other methods for making the search shall be used. One method of making the search is to use a sensitive detector ( e.g. a communication receiver tuned to the IF frequency of the receiver ) and a pickup ( antenna ) which may also be tuned to the IF frequency. By placing the pickup near the later stages of the IF amplifier, the activity of the amplifier can be monitored. When the above procedure is used, changes in the signal in the IF amplifier can be detected and the frequency of the unwanted signal noted.

*f)* Adjust the unwanted signal level at the input of the matching and combining network (4) to equal the reference sensitivity ( data ) determined in 23.3 or 23.5, increased by the specified value of the spurious response immunity data plus the loss of the matching and combining network (4).

*g)* Transmit the standard train of SCTS's for bit stream or character string (see 22.20), or 33 specified messages.

*h)* If there are 25 or less errors for bit stream or character string, or six or less errors for message, record that the receiver-decoder does comply for this unwanted frequency with the spurious response immunity (data) specification.

*i)* Repeat step *e)* through *h)* for other unwanted signal frequencies that may degrade the response of the receiver-decoder.

*j)* If it was recorded in Step *h)* for all of the unwanted frequencies selected in Step *e)* that the receiver-decoder did comply, then record that the receiver-decoder does comply with the spurious response immunity ( data ) specification, otherwise record that it does not comply.

*k)* Record the input signal arrangement used, characteristics of the SCTS ( data ), reference sensitivity ( data ) and specified spurious response immunity ( data ).

## 29. Intermodulation immunity (data)

### 29.1 *Definition*

The ability of the receiver-decoder to prevent two unwanted adjacent signals which have specific frequency relationships to the wanted signal frequency (see Appendix D), from degrading the desired response of the receiver-decoder. It is the ratio, expressed in decibels, of:

*a)* the common level of two unwanted input signals that cause a wanted input signal, which is 3 dB in excess of the reference sensitivity (data), to produce an error ratio equal to the reference error ratio (data),

to

*b)* the reference sensitivity (data).

### 29.2 *Method of measurement for bit stream or character string*

*Note.* — The value of the reference sensitivity (bit stream or character string) determined in Sub-clause 23.3 is required for this measurement.

*a)* Connect the equipment as illustrated in Figure 3 with the switches in position b. Test equipment items (1), (2), (4), (6), (7), (8) and (9) and a comparator are required (see Sub-clause 22.7). Step attenuator (9) will need 0·5 dB steps.

Matching and combining networks (4) and (7) have two inputs and may not have identical losses for each of the inputs. If there is a difference in the losses, it should be accounted for in the calculation of the intermodulation immunity (bit stream or character string).

*b)* Adjust the frequency of the radio-frequency signal generator (2) to one of the specified nominal frequencies.

*c)* Using encoder (1) modulate radio-frequency signal generator (2) with the standard train of coded test signal (bit stream or character string) to generate the standard coded test signal (SCTS) (bit stream or character string) (see Sub-clauses 22.18, 22.19 and 22.20).

*d)* In the absence of the unwanted signal, adjust the signal level at the input of the matching and combining network (4) to be 3 dB in excess of the reference sensitivity (bit stream or character string) determined in Sub-clause 23.3, plus the loss of the matching and combining network (4). Record this value as $R$ in dB ($\mu$V).

*e)* Choose a pair of frequencies, $f_n$ and $f_r$, that may produce an intermodulation response (see Appendix D). Record these frequencies.

*f)* Adjust attenuator (9) to 8 dB.

*g)* Adjust the frequency of radio-frequency generator (6) to $f_n$ and radio-frequency generator (8) to $f_r$.

Adjust the levels of the unwanted signals $f_n$ and $f_r$ to the input of matching and combining network (7) to equal the reference sensitivity (bit stream or character string) multiplied by the ratio of the intermodulation immunity (bit stream or character string), stated in the equipment specification plus the losses of matching and combining networks (7) and (4) plus 8 dB. Record this value as $G$ in dB ($\mu$V).

*h)* Transmit the standard train of SCTS's (see Sub-clause 22.20).

*i)* Calculate and note the error ratio.

*j)* If the error ratio equals the reference error ratio (bit stream or character string), terminate the measurement. Record the attenuation value, $C$, and proceed to Step *b)* of Sub-clause 29.3.

If the error ratio is less than the reference error ratio (bit stream or character string) decrease the attenuation of (9) by 0·5 dB.

If the error ratio is greater than the reference error ratio (bit stream or character string), increase the attenuation of (9) by 0.5 dB.

*k)* Repeat Step *h)* through *j)* until two consecutive values of error ratio have been obtained which bracket the reference error ratio (bit stream or character string). Record the value of attenuation, $A$, that corresponds to the error ratio which is just greater than the reference error ratio (bit stream or character string).

*l)* Repeat Steps *d)* through *k)* using other pairs of unwanted signal frequencies that may produce an intermodulation response.

29.3 *Presentation of results for bit stream or character string*

*a)* Calculate the attenuation, $C$, for each of the unwanted pairs of frequencies as follows:

$$C = A + 0{\cdot}25 \text{ in decibels}$$

where:

$A$ is the attenuation recorded in Step *k)* or *l* of Sub-clause 29.2.

*b)* The intermodulation immunity, $S$, for each of the unwanted pairs of frequencies is:

$$S = G - L - Q - C - R \text{ in dB } (\mu\text{V})$$

where:

$C$ is the value recorded in Step *j)* of Sub-clause 29.2 or calculated in Step *a)*

$G$ is the unwanted input signal level of matching and combining network (7) in dB ($\mu$V) recorded in Step *g)* of Sub-clause 29.2

$L$ is the loss of combining network (7) in decibels

$Q$ is the loss of combining network (4) in decibels

$R$ is the reference sensitivity (bit stream or character string) plus the loss of the matching and combining network (4) recorded in Step *d)* of Sub-clause 29.2

*c)* Record the intermodulation immunity ( bit stream or character string) as the smaller of the values of $S$ calculated in Step *b)*.

*d)* Record the input signal arrangement used, the characteristics of the SCTS (bit stream or character string), the characteristics of the unwanted signals, the frequencies of the unwanted signals and the reference sensitivity (bit stream or character string).

29.4 *Method of measurement for message*

*Note.* — The value of the reference sensitivity (message) determined in Sub-clause 23.5 is required for this measurement.

*a)* Connect the equipment as illustrated in Figure 3 with the switches in position b. Test equipment items (1). (2), (4), (6), (7), (8) and (9) and a comparator are required (see Sub-clause 22.7). Matching and combining networks (4) and (7) have two inputs and may not have identical losses for each of the inputs. If there is a difference in the losses it must be accounted for in the calculation of the intermodulation immunity (message).

*b)* Adjust the frequency of the radio-frequency signal generator (2) to one of the specified nominal frequencies.

*c)* Using encoder (1) modulate radio-frequency signal generator (2) with the reference sequence of messages to generate the standard coded test signal (SCTS) (message) (see Sub-clauses 22.18 and 22.19).

*d)* In the absence of the unwanted signal, adjust the signal level at the input of the matching and combining network (4) to be 3 dB in excess of the reference sensitivity (message) determined in Sub-clause 23.5 plus the loss of the matching and combining network (4). Record this value as $R$ in dB ($\mu$V).

*e)* Choose a pair of frequencies, $f_n$ and $f_r$, that may produce an intermodulation response (see Appendix D). Record these frequencies.

*f)* Adjust the frequency of radio-frequency generator (6) to $f_n$ and radio-frequency generator (8) to $f_r$. Adjust the output of each of the generators to apply the same high signal level [e.g., 100 dB ($\mu$V)] to the matching and combining network (7). Record this level, $A$, in dB ($\mu$V).

*g)* Adjust the step attenuator (9) to a value which will produce a high error ratio (e.g. 50% or greater).

*h)* 1) Transmit the SCTS a maximum of three times, terminating the transmission sequence if the receiver-decoder fails to recognize the SCTS any of those times. Adjust the step attenuator (9) according to Step *h)* 2) or *h)* 3), whichever is appropriate.

2) If the receiver-decoder fails to recognize either the first, second or third SCTS, increase the attenuation of (9) by 2 dB and repeat Step *h)* 1).

3) If the receiver-decoder recognizes the three SCTS's, record the attenuation value in decibels, reduce the attenuation of (9) by 1 dB, record the new attenuation value in decibels, and proceed to Step *i)* 1).

*i)* 1) Transmit the SCTS a maximum of three times, terminating the transmission sequence if the receiver-decoder fails to recognize the SCTS any one of those times. Adjust the step attenuator (9) according to Step *i)* 2) or *i)* 3), whichever is appropriate.

2) If the receiver-decoder fails to recognize either the first, second or third SCTS, increase the attenuation of (9) by 1 dB, record the new attenuation value in decibels and repeat Step *i)* 1). See Step *j)*.

3) If the receiver-decoder recognizes the three SCTS's, reduce the attenuation of (9) by 1 dB, record the new attenuation value in decibels, and repeat Step *i)* 1). See Step *j)*.

*j)* Continue Steps *i)* 1), *i)* 2), and *i)* 3) until attenuator values have been recorded 40 times.

*k)* Repeat Steps *e)* through *j)* using other pairs of unwanted signal frequencies that may degrade the response of the receiver-decoder.

### 29.5 *Presentation of results for message*

*a)* Calculate the average of the attenuation values recorded in decibels in Step *h)* 3), *i)* 2) and *i)* 3) of Sub-clause 29.4 for each of the pairs of unwanted signals.

*b)* Calculate the intermodulation immunity, $S$, for each of the unwanted signals as follows:

$$S = A - B - C - D - R \text{ in decibels}$$

where:

$A$ is the value recorded in Step *f)* of Sub-clause 29.4
$B$ is the average of the attenuation values calculated in Step *a)* in decibels
$C$ is the loss of the combining network (4) in decibels
$D$ is the loss of the combining net work (7) in decibels
$R$ is the reference sensitivity (message) plus the loss of the matching and combining network (4) recorded in Step *d)* of Sub-clause 29.4

*c)* Record the intermodulation immunity (message) as the smaller of the values of $S$ calculated above.

*d)* Record the input signal arrangement used, the characteristics of the SCTS (message), the characteristics of the unwanted signal, the frequencies of the unwanted signals and the reference sensitivity (message).

### 29.6 *Compliance test method — Intermodulation immunity ( data )*

*Note.* — The value of the reference sensitivity ( data ) determined in 23.3 or 23.5 is required for this measurement.

*a)* Connect the equipment as illustrated in Figure 3 with the switches in position b, using test equipment items (1), (2), (4), (6), (7) and (8), and a comparator ( see 22.7 ).

*Note.* — Matching and combining networks (4) and (7) have two inputs and may not have identical losses for each of the inputs. If there is a difference in the losses it should be accounted for in determining the levels of the unwanted signals.

*b)* Adjust the frequency of the radio-frequency signal generator (2) to one of the specified nominal frequencies.

*c)* Using encoder (1), modulate radio-frequency generator (2) with the standard train of coded test signal ( data ) or with the specified message to generate the standard coded test signal ( data ) ( SCTS ) ( see 22.14, 22.18, 22.19 and 22.20 ).

*d)* Adjust the wanted signal level at the input of the matching and combining network (4) to be 3 dB in excess of the reference sensitivity ( data ) determined in 23.3 or 23.5 plus the loss of the matching and combining network (4). Record this value in dB ($\mu$V).

*e)* Choose a pair of frequencies, $f_n$ and $f_r$, that may produce an intermodulation response ( see Appendix D ). Record these frequencies.

*f)* Adjust the frequency of radio frequency generator (6) to $f_n$ and radio-frequency generator (8) to $f_r$.

*g)* Adjust the unwanted signal levels of $f_n$ and $f_r$ at the input of matching and combining network (7) to equal the reference sensitivity ( data ) determined in 23.3 or 23.5, increased by the specified value of the intermodulation immunity ( data ), plus the the losses of matching and combining network (7) and (4). Record this value in dB ($\mu$V).

*h)* Transmit the standard train of SCTS's for bit stream or character string ( see 22.20 ), or 33 specified messages.

*i)* If there are 25 or less errors for bit stream or character string, or six or less errors for message, record that the receiver--decoder for this pair of unwanted frequencies does comply with the intermodulation immunity ( data ) specification.

*j)* Repeat Steps *e)* through *i)* for other unwanted frequency pairs that may degrade the response of the receiver-decoder.

*k)* If it was recorded in Step *j)* for all of the unwanted frequency pairs selected in Step *e)* that the receiver-decoder did comply, then record that the receiver-decoder does comply with the intermodulation immunity ( data ) specification, otherwise record that it does not comply.

*l)* Record the input signal arrangement used, characteristics of the SCTS ( data ), the reference sensitivity ( data ) and the specified intermodulation immunity ( data ).

## 30. Sensitivity reduction under multipath propagation conditions (data)

Variations of amplitude and phase of a radio-frequency signal are created by multipath reflections in the propagation medium whenever the transmitting or receiving antennas are in motion. These signal variations are a function of both the antenna velocity and the radio-frequency of the desired signal.

The resulting variations of signal amplitude and phase show a Rayleigh distribution in limited areas where the direct signal is missing. They can be simulated by an appropriate method of modulating both the envelope and phase.

### 30.1 *Definition*

The ability of the receiver-decoder to minimize the degradation of its response caused by variations of amplitude and phase of the input signal due to multipath propagation conditions. It is the ratio, expressed in decibels, of:

*a)* the r.m.s. value of a Rayleigh faded input signal level that produces the reference error ratio (data), to

*b)* the reference sensitivity (data).

30.2 *Method of measurement for bit stream and character string*

*Note.* — The value of the reference sensitivity ( bit stream or character string ) determined in Sub-clause 23.3 is required for this measurement.

*a)* Connect the equipment as illustrated in Figure 4 (see Appendix C for details of the Rayleigh fading simulator). A comparator is also needed (see Sub-clause 22.7).

*b)* Adjust the frequency of the radio-frequency signal generator (2) to one of the specified nominalfrequencies.

*c)* Using encoder (1) modulate the radio-frequency signal generator (2) with the standard train of coded test signal (bit stream or character string) to generate the standard coded test signal (SCTS) (bit stream or character string) (see Sub-clauses 22.18, 22.19 and 22.20).

*d)* Adjust the Rayleigh fading simulator (3) for a velocity of 100 km/h if the receiver-decoder under test is mobile or 10 km/h if the receiver-decoder under test is portable.

*e)* Record the r.m.s. value of the output signal, $J$, of the Rayleigh fading simulator in dB ($\mu$V).

*f)* Adjust the attenuator (4) to produce a radio-frequency input signal level to the input of the receiver-decoder, equal to the reference sensitivity (bit stream or character string) multiplied by the ratio of the sensitivity reduction under multipath propagation conditions (bit stream or character string) as stated in the equipment specification to the nearest decibel. Record the reference sensitivity (bit stream or character string) determined in Sub-clause 23.3 as $R$.

*g)* Transmit the standard train of SCTS's (see Sub-clause 22.20).

*h)* Calculate and note the error ratio.

*i)* If the error ratio equals the reference error ratio (bit stream or character string), terminate the measurement. Record the attenuation, $M$, of step attenuator (4) and proceed to Step *b)* of Sub-clause 30.3.

If the error ratio is less than reference error ratio (bit stream of character string), decrease the attenuation by 1 dB.

If the error ratio is greater than the reference error ratio (bit stream or character string), increase the attenuation by 1 dB.

*j)* Repeat Steps *g)* through *i)* until two consecutive values of error ratio have been obtained which bracket the reference error ratio (bit stream or character string). Record the value of attenuation, $A$, that corresponds to the error ratio which is just greater than the reference error ratio (bit stream or character string).

*k)* Repeat Steps *d)* through *j)* for velocities of 50, 20 and 10 km/h if the receiver-decoder under test is mobile or 5, 2 and 1 km/h if the receiver-decoder under test is portable.

30.3 *Presentation of results for bit stream or character string*

*a)* Calculate the attenuator values, $M$, for the four velocities as follows:

$$M = A - 0{\cdot}5 \text{ in decibels}$$

where:

$A$ is the attenuation recorded in Step *j)* of Sub-clause 30.2.

*b)* Calculate the sensitivity reduction under multipath propagation conditions (bit stream or character string), $S$, in decibels, for each velocity using:

$$S = J - M - R \quad \text{in decibels}$$

where:

$J$ is the r.m.s. level of the output of the Rayleigh fading simulator in dB ($\mu$V), recorded in Step *e)* of Sub-clause 30.2.

$M$ is the value recorded in Step *i)* of Sub-clause 30.2 or calculated in Step *a)* in decibels

$R$ is the reference sensitivity (bit stream or character string) in dB ($\mu$V) determined in Sub-clause 23.3

*c)* Record the input signal arrangement used, the characteristics of the SCTS (bit stream or character string), the velocities and the sensitivity reductions under multipath propagation conditions (bit stream or character string) and the reference sensitivity (bit stream or character string).

### 30.4 *Method of measurement for message*

*Note.* — The value of the reference sensitivity (message) determined in Sub-clause 23.5 is required for this measurement.

*a)* Connect the equipment as illustrated in Figure 4 (see Appendix C for details of the Rayleigh fading simulator). A comparator is also needed (see Sub-clause 22.7).

*b)* Adjust the frequency of the radio-frequency signal generator (2) to one of the specified nominal frequencies.

*c)* Using the encoder (1) modulate the radio-frequency signal generator (2) with the reference sequence of messages to generate the standard coded test signal (SCTS) (message) (see Sub-clauses 22.18 and 22.19).

*d)* Adjust the Rayleigh fading simulator (3) for a velocity of 100 km/h if the receiver-decoder under test is mobile or 10 km/h if the receiver-decoder under test is portable.

*e)* Record the r.m.s. value of the output signal, $J$, of the Rayleigh fading simulator in dB ($\mu$V).

*f)* Adjust the attenuator (4) to a value which will produce a high error ratio (e.g. 50% or greater).

*g)* 1) Transmit the SCTS a maximum of three times, terminating the transmission sequence if the receiver-decoder fails to recognize the SCTS any one of those times. Adjust the step attenuator (4) according to Step *g)* 2) or *g)* 3), whichever is appropriate.

2) If the receiver-decoder fails to recognize either the first, second or third SCTS, reduce the attenuation of (4) by 2 dB and repeat Step *g)*1).

3) If the receiver-decoder recognizes the three SCTS's, record the attenuation value in decibels, increase the attenuation of (4) by 1 dB, record the new attenuation value in decibels, and proceed to Step *h)*1).

*h)* 1) Transmit the SCTS a maximum of three times, terminating the transmission sequence if the receiver-decoder fails to recognize the SCTS any one of those times. Adjust the step attenuator (4) according to Step *h)*2) or *h)*3), whichever is appropriate.

2) If the receiver-decoder fails to recognize either the first, second or third SCTS, reduce the attenuation of (4) by 1 dB, record the new attenuation value in decibels, and repeat Step *h)*1). See Step *i)*.

3) If the receiver-decoder recognizes the three SCTS's, increase the attenuation of (4) by 1 dB, record the new attenuation value in decibels, and repeat Step *h)*1). See Step *i)*.

*i)* Continue Steps *h)*1), *h)*2) and *h)*3) until attenuator values have been recorded 40 times.

*j)* Repeat Steps *d)* through *i)* for velocities of 50, 20 and 10 km/h if the receiver-decoder under test is mobile or 5, 2 and 1 km/h if the receiver-decoder under test is portable.

30.5 *Presentation of results for message*

*a)* Calculate the average of the attenuation values recorded in decibels in Steps *g)*3), *h)*2) and *h)*3) of Sub-clause 30.4 for each velocity.

*b)* The sensitivity reduction under multipath propagation conditions (message), *S*, is given by the following:

$$S = J - B - R \text{ in decibels}$$

where:

$J$ is the value recorded in Step *e)* of Sub-clause 30.4

$B$ is the average of the attenuation values calculated in Step *a)* in decibels

$R$ is the reference sensitivity (message) in dB ($\mu$V) determined in Sub-clause 23.5

*c)* Record the input signal arrangement used, the characteristics of the SCTS (message), the velocities and the sensitivity reductions under multipath propagation conditions (message), and the reference sensitivity (message).

30.6 *Compliance test method — sensitivity reduction under multipath propagation condition ( data )*

*Note.* — The value of the reference sensitivity ( data ) determined in 23.3 or 23.5 is required for this measurement.

*a)* Connect the equipment as illustrated in Figure (4) and include a comparator ( see Appendix C for details of the Rayleigh fading simulator and 22.7 for the comparator ).

*b)* Adjust the frequency of the radio-frequency signal generator (2) to one of the specified nominal frequencies.

*c)* Using encoder (1), modulate radio-frequency signal generator (2) with the standard train of coded test signal ( data ) or with the specified message to generate the standard coded test signal ( data ) ( SCTS ) ( see 22.14, 22.18, 22.19 and 22.20 ).

*d)* Adjust the Rayleigh fading simulator (3) for a velocity of 100 km/h if the receiver-decoder under test is a mobile or 10 km/h if the receiver-decoder under test is a portable.

*e)* Record the r.m.s. value of the output signal, *J*, of the Rayleigh fading simulator in dB ($\mu$V).

*f)* Adjust the attenuator (4) to produce a radio-frequency input level at the input of the receiver-decoder, equal to the reference sensitivity ( data ) determined in 23.3 or 23.5, increased by the specified value of the sensitivity reduction under multipath propagation conditions ( data ). Record the reference sensitivity ( data ).

*g)* Transmit the standard train of SCTS's for bit stream or character string ( see 22.20 ), or 78 specified messages.

*h)* If there are 25 or less errors for bit stream or character string, or 15 or less errors for message, record that the receiver-decoder does comply for this velocity with the specified sensitivity reduction under multipath propagations conditions ( data ) specification.

*i)* Repeat steps *d)* through *h)* for velocities of 50, 20 and, 10 km/h if the receiver-decoder under test is a mobile, or 5, 2 and 1 km/h if the receiver-decoder under test is a portable.

*j)* If it was recorded in step *h)* for all the velocities selected in step *d)* that the receiver-decoder did comply, then record that the receiver-decoder does comply with the specified sensitivity reduction under multipath propagations ( data ) specification, otherwise record that it does not comply.

*k)* Record the characteristics of the SCTS ( data ), the reference sensitivity ( data ) and the specified sensitivity reduction under multipath propagations conditions ( data ).

## SECTION FIVE — MEASUREMENTS OF RECEIVER-DECODER CONDUCTED AND RADIATED SPURIOUS COMPONENTS (DATA AND SELECTIVE CALLING)

### 32. Conducted spurious components (data and selective calling)

### 32.1 *Definition*

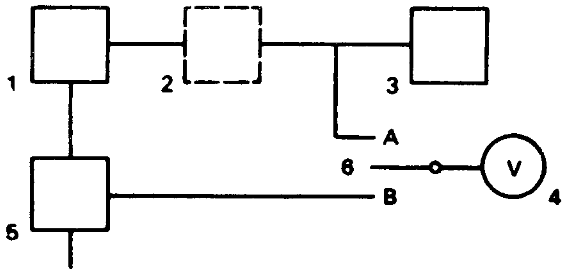
Conducted spurious components are radio-frequency components that are usually characterized by having a dominant component at a discrete frequency or in a narrow band of frequencies. They may be present at the antenna or a.c. power terminals of the receiver.

### 32.2 *Method of measurement of antenna terminal conducted spurious components*

*a)* Connect the equipment as shown in Figure 8.

*b)* With the receiver operating, adjust the frequency of the selective measuring device (4) over the specified range of measurements to search for the spurious components.

*c)* Record the frequency and level of each spurious component found.



**Power mains**

1 = receiver under test
2 = artificial antenna, if required (see Sub-clause 5.2.2)
3 = test load
4 = selective measuring device
5 = mains power line impedance stabilization (isolation) network
6 = switch

FIG. 8. — Measuring arrangement for antenna terminal and a.c. power terminal conducted spurious components.

*Notes 1.* — For the purpose of this measurement, the impedance of the test load (3) including the effect of the selective measuring device (4) should be equal to the source impedance required by the artificial antenna (or the receiver).

*2.* — Measurement precautions: Precautions should be taken to prevent interfering voltages from entering the measuring equipment, either by radiation or through the mains supply leads.

*3.* — This test method is limited to the case of metre and decimetre wavelengths since the voltage measured across a test load connected to the antenna terminals is not representative of the interference in the case of hectometre waves. In the case of a ship, the result obtained, when the installation is built, depends to a considerable extent on the position of the antenna with respect to the superstructure.

### 32.3 *Presentation of results*

The levels recorded in Step *c)* of Sub-clause 32.2 expressed as a voltage or as a power, are the antenna terminal conducted spurious components. Record their frequency and the impedance of the test load. Record the component values of the artificial antenna and of the test load. Also record the characteristic impedance and the length of the cable between the receiver and the artificial antenna.

32.4 *Method of measurement of a.c. power terminal conducted spurious components (for frequencies below 30 MHz)*

*a)* The asymmetrical components are measured using the arrangement shown in Figure 8 but with switch (6) in position B.

*Note.* — An example of a mains power line impedance stabilization (isolation) network, also known as an artificial mains network, is given in Appendix N.

*b)* With the receiver operating, adjust the frequency of the selective measuring device (4) over the specified range of measurements to search for the spurious components.

*c)* Record the frequency and level of each spurious component found, along with the attenuation due to the mains power line stabilization (isolation) network.

32.5 *Presentation of results*

The levels recorded in Step *c)* of Sub-clause 32.4 corrected for loss of the mains power line impedance stabilization (isolation) network and expressed as a voltage or as a power, are the a.c. power terminal conducted spurious components.

32.6 *Method of measurement at the a.c. power terminal (for frequencies up to 1 000 MHz)*

No requirement at this time.

## 33. Radiated spurious components (data and selective calling)

33.1 *Definition*

Any radiation originating from within a receiver.

33.2 *Method of measurement* (see Figure 9 )

*a)* Select the test site, suitable for the range of frequencies and power levels to be measured, from those described in Appendices K or L.

*b)* Connect the equipment as illustrated in the chosen appendix. If the receiver has an antenna terminal, it shall be terminated in a test load having an impedance equal to the nominal radio-frequency input impedance.

*c)* Operate the receiver.

*d)* Identify the frequencies of the significant spectral radiated spurious components by using a selective measuring device. If necessary, closely couple it to the receiver under test.

*e)* Adjust the measuring antenna (if adjustable) to the correct length for the frequency of one of the significant spectral radiated spurious components identified in Step *d)*.

*f)* Tune the selective measuring device to the considered significant spectral radiated spurious component.

*Note.* — Deactivate the receiver under test to verify that it is the origin of the radiated spurious component in Step *f)*.

*g)* Position the measuring antenna for vertical polarization.

*h)* Rotate the equipment under test to obtain the maximum indication on the selective measuring device.

*i)* When required by the test site description, raise and lower the measuring antenna to obtain the maximum indication on the selective measuring device.

*j)* Repeat Steps *h)* and *i)* until no further increase occurs. Note the frequency and the maximum indication.

*k)* Position the measuring antenna for horizontal polarization and repeat Steps *h)*, *i)* and *j)*.

*l)* Repeat Steps *e)* to *k)* until the levels have been measured for all significant spectral radiated spurious components identified in Step *d)*.

*m)* Replace the receiver under test by a vertical auxiliary antenna.

*n)* Select one of the significant spectral radiated spurious components measured in Step *j)* and adjust the frequency of the radio-frequency signal generator to its frequency.

*o)* Adjust the length of the auxiliary antenna (if adjustable) for the considered frequency.

*p)* Adjust the length of the measuring antenna (if adjustable) for the considered frequency.

*q)* Tune the selective measuring device to the considered frequency.

*r)* Position the measuring antenna for vertical polarization.

*s)* Adjust the output level of the radio-frequency signal generator to provide an indication on the selective measuring device.

*t)* When required by the test site description, raise and lower the measuring antenna to provide a maximum indication on the selective measuring device.

*u)* Readjust the output level of the radio-frequency signal generator to obtain the same value of indication as noted in Step *j)*. Note the output level of the radio-frequency signal generator and its frequency.

*v)* Repeat Steps *s)* to *u)* with the auxiliary and measuring antennas horizontally polarized.

*w)* Repeat Steps *n)* to *v)* for the remaining significant spectral radiated components measured in Step *j)*.

### 33.3 *Presentation of results*

Calculate the power available to the auxiliary antenna from the values noted in Step *u)* of Sub-clause 33.2 taking into account the different settings of the attenuator, the gain of the auxiliary antenna and the cable loss between the radio-frequency signal generator and the auxiliary antenna.

The power of the radiated spurious component is defined as the largest of the values thus calculated.

Record this power and the frequency of the corresponding spectral radiated spurious component.

If necessary, show the power of the other significant spectral radiated spurious components.

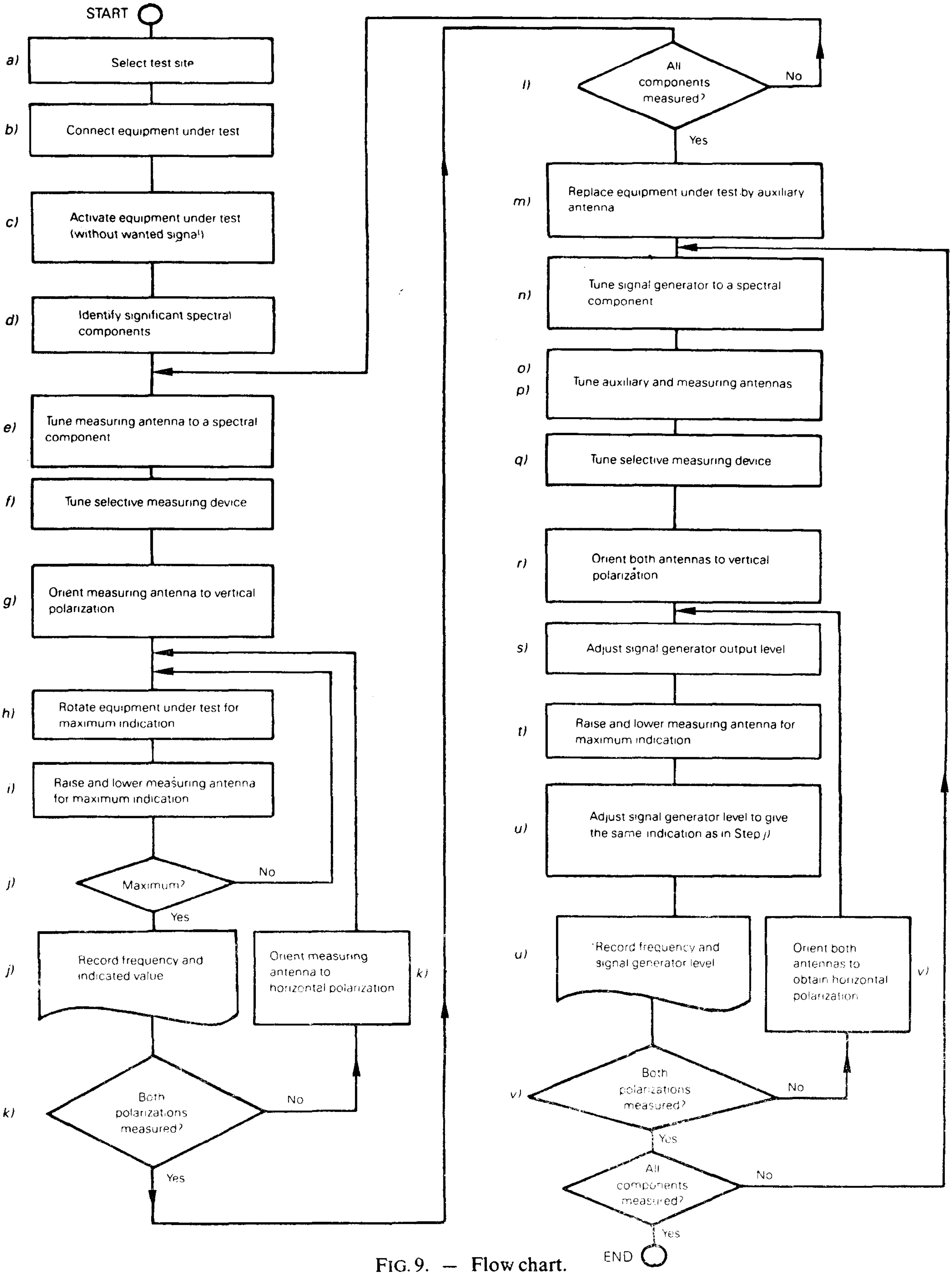

START
a) Select test site
b) Connect equipment under test
c) Activate equipment under test (without wanted signal)
d) Identify significant spectral components
e) Tune measuring antenna to a spectral component
f) Tune selective measuring device
g) Orient measuring antenna to vertical polarization
h) Rotate equipment under test for maximum indication
i) Raise and lower measuring antenna for maximum indication
j) Maximum?
No
Yes
j) Record frequency and indicated value
k) Orient measuring antenna to horizontal polarization
k) Both polarizations measured?
No
Yes
l) All components measured?
No
Yes
m) Replace equipment under test by auxiliary antenna
n) Tune signal generator to a spectral component
o) p) Tune auxiliary and measuring antennas
q) Tune selective measuring device
r) Orient both antennas to vertical polarization
s) Adjust signal generator output level
t) Raise and lower measuring antenna for maximum indication
u) Adjust signal generator level to give the same indication as in Step j)
u) Record frequency and signal generator level
v) Orient both antennas to obtain horizontal polarization
v) Both polarizations measured?
No
Yes
All components measured?
No
Yes
END

FIG. 9. — Flow chart.

## SECTION SIX — MEASUREMENTS OF ENCODER-TRANSMITTERS RADIO-FREQUENCY PARAMETERS (DATA AND SELECTIVE CALLING)

Clauses 34 to 38 ( *under consideration* )

## SECTION SEVEN — AUDIO-FREQUENCY BAND MEASUREMENTS OF ENCODER OUTPUT CHARACTERISTICS (SELECTITE CALLING)

### 39. Tone pulse-rise time (selective calling)

39.1 *Definition*

The tone pulse-rise time is the interval between the instants during which the amplitude of the pulse envelope increases from 10% to 90% of its steady-state value.

39.2 *Method of measurement*

*a)* Terminate the encoder output with the load specified by the manufacturer.

*b)* Connect the vertical display of an oscilloscope in parallel with the output load and adjust the encoder in accordance with the manufacturer's instructions. Derive the synchronizing pulse for the calibrated horizontal sweep of the oscilloscope from the signal that starts the encoder sequence.

*c)* Arrange for the encoder to send a single standard coded test signal and measure the interval between the instants during which the pulse envelope value increases from 10% to 90% of its steady-state value.

*d)* This measurement may be repeated for any other coded signal.

### 40. Tone pulse duration (selective calling)

40.1 *Definition*

The duration of a tone pulse is the interval between the first and last instants during which the amplitude of the pulse envelope exceeds 50% of its steady-state value.

40.2 *Method of measurement*

*a)* Terminate the encoder output with the load impedance specified by the manufacturer.

*b)* Connect the vertical display of an oscilloscope in parallel with the output load and adjust the encoder in accordance with the manufacturer's instructions. Derive the synchronizing pulse for the calibrated horizontal sweep of the oscilloscope from the signal that starts the encoder sequence.

*c)* Arrange for the encoder to send a single tone pulse and measure the interval between the first and last instants during which the amplitude of the pulse envelope exceeds 50% of its steady-state value.

*d)* This measurement may be repeated for any other tone pulses.

*e)* For sequential tone systems, this method can be used to determine:

- — the duration of individual tone pulses;
- — the pulse-spacing time, for example, the interval during which the amplitude of the pulses is less than 10% of the maximum amplitude;
- — the total duration of a single coded signal.

## 41. Tone pulse-decay time (selective calling)

### 41.1 *Definition*

The tone pulse-decay time is the interval between the instants during which the amplitude of the pulse envelope decreases from 90% to 10% of its steady-state value.

### 41.2 *Method of measurement*

*a)* Terminate the encoder output with the load specified by the manufacturer.

*b)* Connect the vertical display of an oscilloscope in parallel with the output load and adjust the encoder in accordance with the manufacturer's instructions. Derive the synchronizing pulse for the calibrated horizontal sweep of the oscilloscope from the signal that starts the encoder sequence.

*c)* Arrange for the encoder to send a single standard coded test signal and measure the time interval during which the amplitude of the pulse envelope decreases from 90% to 10% of its steady-state value.

## 42. Frequency of tone(s) (selective calling)

### 42.1 *Definition*

The frequency of the tone(s) is the fundamental frequency (or frequencies) of the tone(s) within the duration of one tone pulse.

### 42.2 *Method of measurement*

*a)* Terminate the output of the encoder with the load specified by the manufacturer.

*b)* Connect a period-measuring device in parallel with the output load.

*c)* Arrange for the encoder to send a single tone pulse.

*d)* Start the period-measuring device after the pulse envelope has reached its steady-state value.

*e)* Measure the period of at least 10 cycles of the tone frequency and compute the frequency from the period thus measured.

*Note.* — Alternatively, the frequency of a single-tone pulse may be measured with a frequency-counting test instrument if the tone pulse duration is significantly longer than the counting period of the measuring instrument.

*f)* For sequential tone systems, arrange for the encoder to send each tone pulse individually.

*g)* For simultaneous tone systems, band-pass filters, at the nominal frequency of the tone required to be measured, should be used to reject all other tones.

## 43. R.M.S. voltage of tone(s) (selective calling)

### 43.1 *Definition*

The r.m.s. voltage of the tone output of the decoder is the r.m.s. voltage of the tone pulse measured when the output is correctly terminated.

### 43.2 *Method of measurement*

*a)* Terminate the encoder output with the load specified by the manufacturer.

*b)* Connect the vertical input of an oscilloscope in parallel with the output load and adjust the encoder according to the manufacturer's operating instructions.

*c)* Arrange for the encoder to send a single coded signal. Measure the peak-to-peak amplitude of any or all of the tone pulses.

*d)* Because the amplitude of the tones may depend on the tone frequency, measurements should be repeated until all possible tones have been measured.

*e)* For simultaneous tone systems, band-pass filters at the nominal frequencies of the coded signal should be used to reject all tones except the one to be measured.

*f)* The peak-to-peak values should be converted to r.m.s. values, assuming that the tones are sinusoidal.

*Note.* — If the manufacturer provides a facility for adjustment to the amplitude, both the maximum and minimum amplitudes obtained should be recorded.

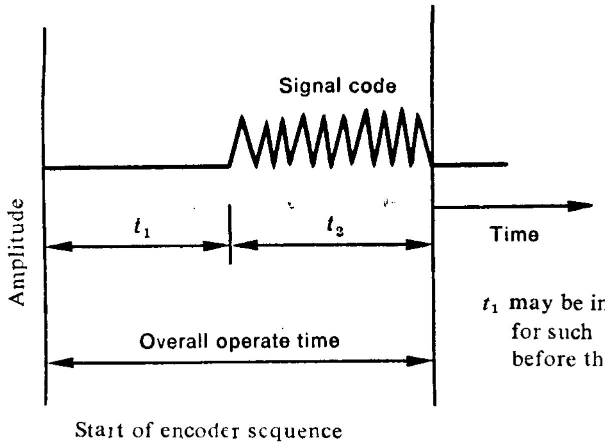
43.3 *Presentation of results*

If a large number of tones is involved, the results should be recorded in graphical form.

## 44. Encoder overall operate time ( selective calling )

44.1 *Definition*

The encoder overall operate time is the elapsed time from the start of the encoder enabling sequence until the complete coded signal has been observed at the output terminals.



$t_1$ may be incorporated in the operate time to provide for such other events as transmitter attack time before the signal code is sent in interval $t_2$.

FIGURE. 10

44.2 *Method of measurement*

*a)* Terminate the encoder output with the load specified by the manufacturer.

*b)* Connect the vertical display of an oscilloscope in parallel with the output load and adjust the encoder according to the manufacturer's instructions. Derive the synchronizing pulse for the calibrated horizontal scan of the oscilloscope from the signal that starts the encoder sequence.

*c)* Arrange for the encoder to send a single standard coded test signal and measure the overall operate time from the start of the scan until the amplitude of the envelope of the final pulse has fallen to 50% of its steady-state value.

*d)* The measurement should be repeated for all coded signals having different *initial* tone frequencies.

44.3 *Presentation of results*

If the encoder overall operate is dependent on the initial tone frequency, the results should be recorded on a graph showing operate time versus frequency.

## SECTION EIGHT — AUDIO-FREQUENCY BAND MEASUREMENTS OF DECODER CHARACTERISTICS (SELECTIVE CALLING)

### 45. Decoder operation level range ( selective calling )

45.1 *Definition*

The decoder operating level range is the range of input levels over which the calling probability exceeds a specified value. Each input level of this range shall be expressed by its ratio in decibels to the nominal input level, specified by the manufacturer.

45.2 *Method of measurement*

*a)* Connect the equipment as shown in Figure 11.

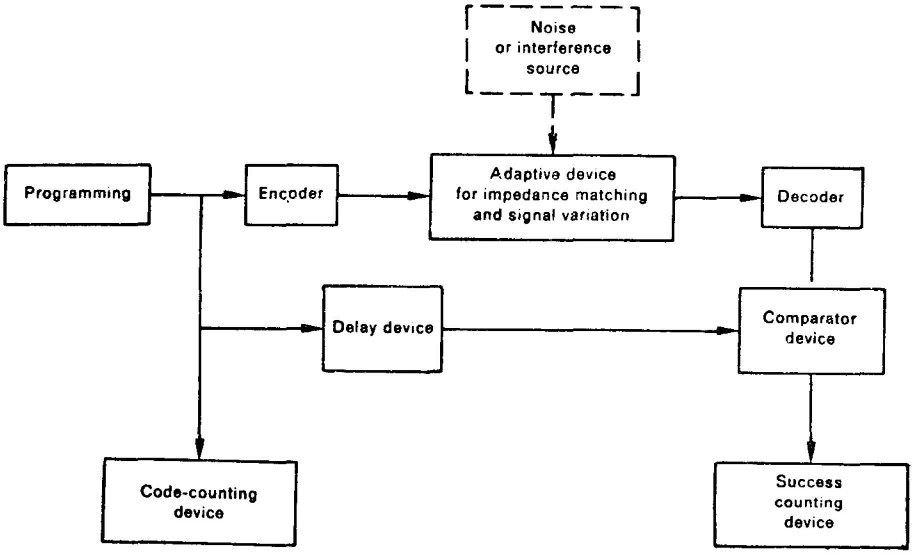


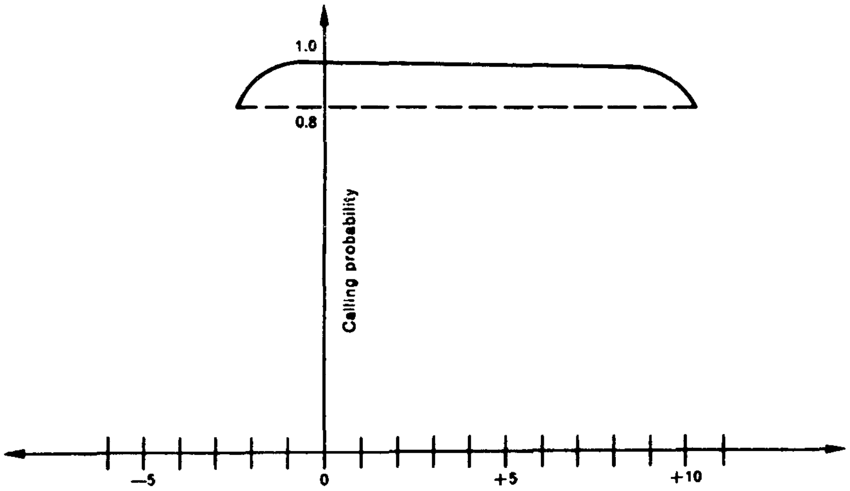
FIG. 11.—Typical measuring arrangement.

*b)* Apply the standard coded test signal to the input of the decoder at the nominal input level through a matching network as specified by the manufacturer.

*c)* Vary the input level in steps of 1 dB both below and above the specified nominal level and record the number of successful calls at each input level. Continue to vary the input level in steps of 1 dB until the calling probability is less than 80%.

45.3 *Presentation of results*

Plot decoder relative input level versus calling probability as shown in Figure 12. Record the input level corresponding to 0 dB. Record the number of trials.



Relative input level (dB) O (db) Corresponds to.........volts

FIG. 12.

## 46. Decoder attack time (selective calling)

### 46.1 *Definition*

The decoder attack time is the elapsed time from the instant that its intended coded signal at the decoder input terminals exceeds 10% of the maximum steady-state value until the decoder successfully responds. If the response is an audio output, successful response is 50% of the maximum steady-state output voltage (see Figure 13).

For multi-tone decoders, the manufacturer shall specify the characteristics of the coded signal.

### 46.2 *Method of measurement*

*a)* Apply a standard coded test signal to the input of the decoder at the nominal input level through a matching network as specified by the manufacturer.

*b)* Display the input voltage to the decoder on one beam of a double-beam oscilloscope and connect the other beam across the alarm indicating circuits.

*c)* Measure the elapsed time from when the input signal exceeds 10% of its maximum level to the time when the alarm circuit has reached 50% of its steady-state output voltage.

*Note.* — When the alarm circuit is only a means of de-muting an associated receiver, it may be necessary to feed an audio-frequency tone into the auxiliary circuit of the decoder to measure an audio response.

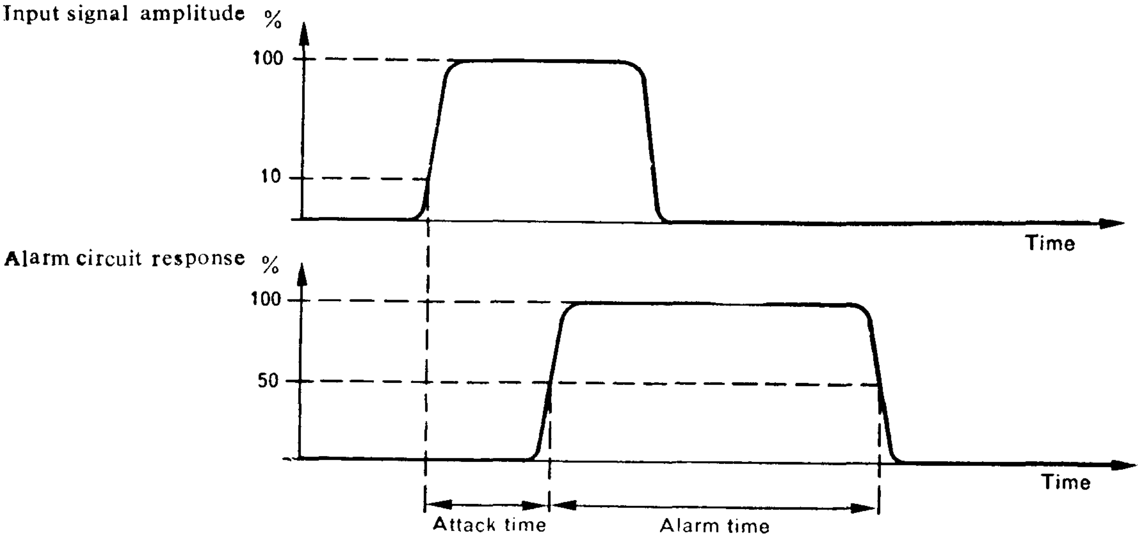


FIG. 13.

## 47. Decoder recovery time (selective calling)

### 47.1 *Definition*

The decoder recovery time is the minimum time that is needed between two successive encoded calling sequences to achieve a successful decoder response on the second encoder sequence.

This characteristic can be observed only when the decoder automatically resets.

47.2 *Method of measurement*

*a)* Connect an encoder or code simulator to the decoder, with means of recording the number of successful calls (see Figure 11).

*b)* Arrange that the interval between two successive coded signals can be progressively varied from zero to a time equal to at least twice the recovery time stated by the manufacturer.

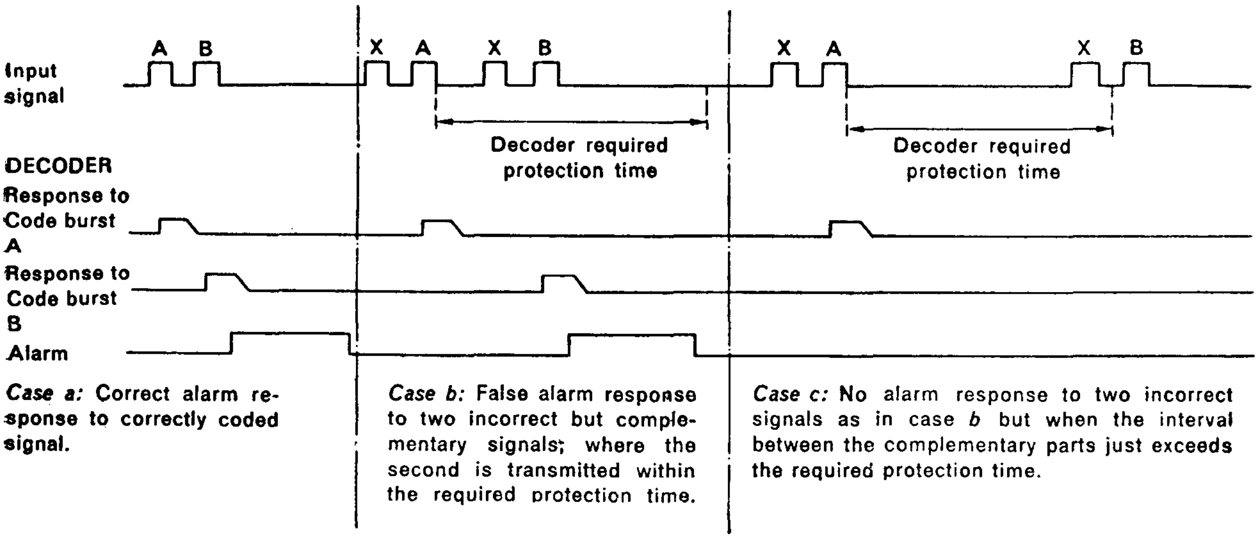
*c)* With the time interval at maximum, ensure that a satisfactory success rate is obtained. Reduce the time interval until a significant number of failures is observed, for example, up to 20%.

This time interval is the decoder recovery time.

## 48. Decoder required protection time (selective calling)

48.1 *Definition*

The decoder required protection time is the maximum time during which a partially operated decoder may respond to other coded signals containing the complementary part of the standard coded test signal (see Figure 14).



***Case a:*** **Correct alarm response to correctly coded signal.**

*Case b:* False alarm response to two incorrect but complementary signals; where the second is transmitted within the required protection time.

*Case c:* No alarm response to two incorrect signals as in case *b* but when the interval between the complementary parts just exceeds the required protection time.

FIG. 14.

48.2 *Method of measurement*

*a)* Connect an enoder or code simulator to the decoder, with means of recording the number of successful calls (see Figure 11).

*b)* Arrange that the encoder initially sends the first part of a particular code and after an interval adjustable up to the recovery time, sends the remaining part of the code.

*c)* With the time interval set to a minimum, ensure that a satisfactory success rate is obtained. Increase the time interval until a significant number of failures is observed, i.e. up to 20%. This time interval is the decoder protection time.

*Note.* — The decoder must be protected from complementary signals until they no longer result in a significant percentage positive responses.

*d)* In individual tone sequential system having more than two tones, it may be necessary to repeat this measurement with the time interval inserted in different positions of the code sequence.

### 49. Decoder alarm time ( selective calling )

49.1 *Definition*

The decoder alarm time is the elapsed time between a successful decoder alarm response, i.e. the output voltage exceeding 50% of its maximum steady-state value, and at cessation of alarm, the decrease of the output voltage to this 50% value (see Figure 13).

This characteristic can be observed only when the alarm is fitted with automatic cancellation.

49.2 *Method of measurement*

*a)* Arrange to display the alarm signal on an oscilloscope which has a calibrated time base.

*Note.* — Should the alarm signal be of a form which cannot be readily displayed, then it may be necessary to arrange for an auxiliary signal to be provided to enable the measurement to be made, for example, an audiofrequeacy-tone, a d.c. voltage, etc.

*b)* Apply a standard coded test signal through a matching network, as specified by the manufacturer, to the input of the decoder, at the nominal input level.

*c)* Measure the duration of the alarm signal, i.e. the time from when the alarm signal first exceeds 50% of the maximum steady-state amplitude to when it falls to the 50% value (see Figure 13).

*d)* If the alarm time is dependent upon the coded signal, the measurement should be repeated for the limiting values of the controlling element of the coded signal.

## SECTION NINE — OVERALL MEASUREMENTS IN SIMULATED SYSTEMS (SELECTIVE CALLING)

### 50. General

In this section, system measurements are described in which the radio-frequency transmission medium must be simulated. It is imperative that the measuring arrangement is such that the test results will not be affected by undesired coupling between the transmitter and receiver.

### 51. Supplementary conditions of measurement for system response times

*a)* Connect the system to be measured as shown in Figure 15.

*b)* Except for continuous individual-tone systems, adjust the radio-frequency attenuation to produce the reference signalling sensitivity for the receiver/decoder.

*c)* For continuous individual-tone systems, adjust the radio-frequency attenuation to produce the standard input signal level at the receiver antenna terminals.

### 52. System overall operate time ( selective calling )

52.1 *Definition*

The system overall operate time is the elapsed time from the start of the encoder-enabling signal, this instant being simultaneous with the start of the transmit function and the moment when the decoder alarm successfully responds. If the response is an audio output, successful response is when the audio output reaches 50% of the maximum steady-state output voltage (see Figure 16).

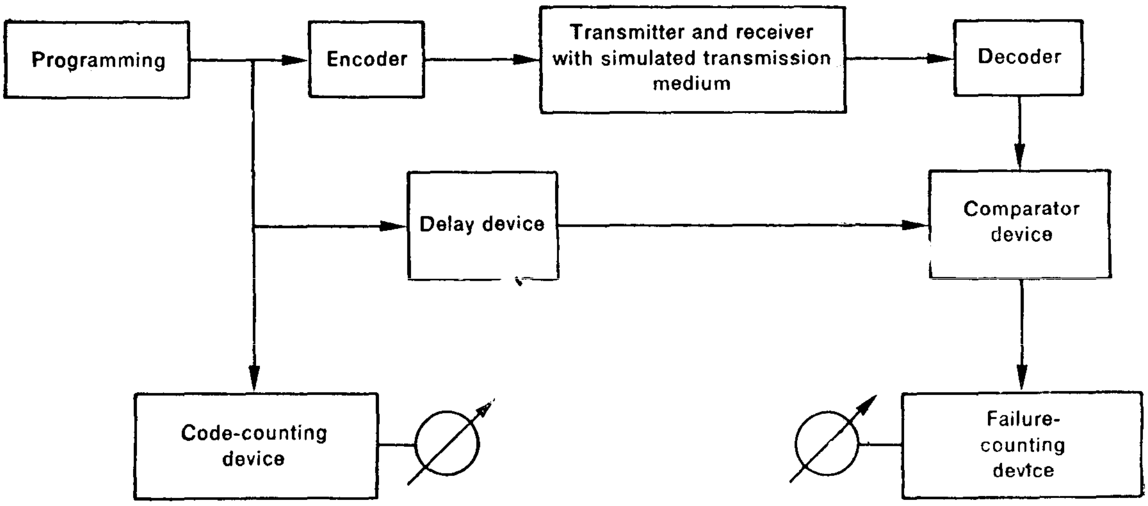


FIG. 15. — Typical measuring arrangement.

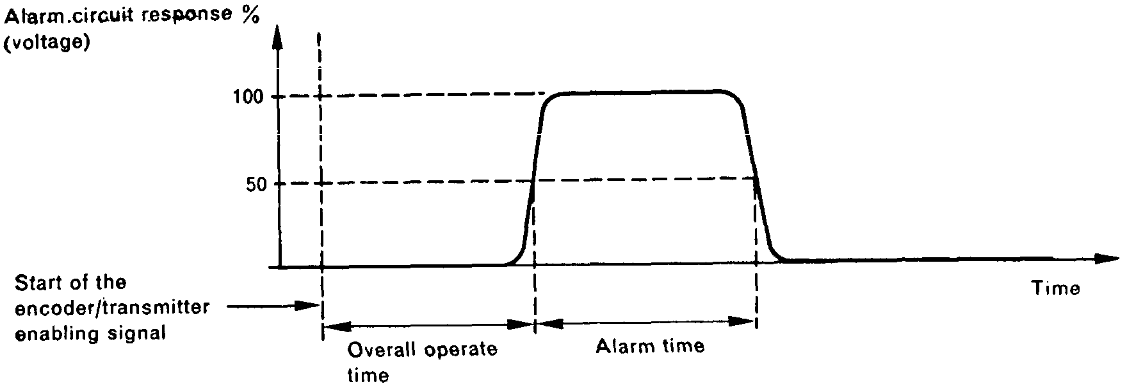


FIG. 16.—System overall operate and alarm time.

*Note.* — This method of measurement applies only when the encoder and transmitter are enabled simultaneously.

52.2 *Method of measurement*

*a)* Connect the vertical display of an oscilloscope in parallel with the decoder alarm initiating circuit.

*b)* Derive the synchronizing pulse for the calibrated horizontal sweep of the oscilloscope from the encoder-enabling signal.

*c)* The system overall operate time is the interval between the start of the encoder-transmitter enabling signal and the moment when the decoder alarm-initiating circuit respone reaches 50% of the maximum steady-state output voltage.

*d)* Repeat this measurement for all coded signals having different *initial* tone frequencies.

*Note.* — When the alarm circuit is only a means of de-muting the associated receiver, it may be necessary to simultaneously apply standard test modulation to the transmitter to measure the audio response or, alternatively, the rise-time of the signal that performs the de-muting function.

### 52.3 *Presentation of results*

If the overall operate time is dependent on the *initial* tone frequency, the results should be recorded on a graph showing overall operate time versus initial tone frequency.

## 53. System recovery time (selective calling)

### 53.1 *Definition*

The system recovery time is the minimum time needed between two successive encoded calling sequences to achieve a successful decoder response on the second encoder sequence.

This characteristic can be measured only when the decoder automatically resets.

### 53.2 *Method of measurement*

*a)* Connect an encoder or code simulator to the transmitter with a means of recording the number of successful calls.

*b)* Arrange that the interval between two successive coded signals can be varied fromz ero to a time at least twice the recovery time stated by the manufacturer.

With the time interval at maximum, ensure that a satisfactory success rate is obtained. Reduce the time interval until a sginificant number of failures is observed, for example up to 20%.

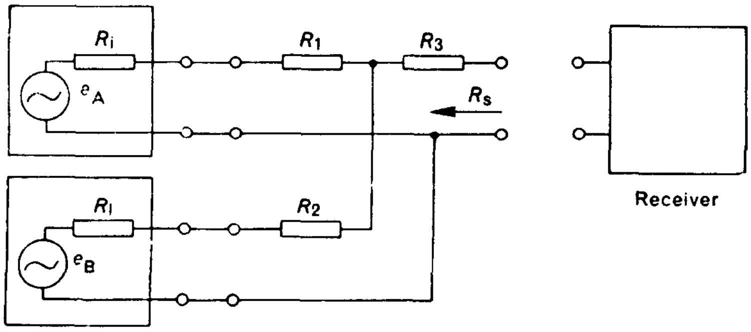
This time interval is the system recovery time.

# APPENDIX A

## EXAMPLES OF COMBINING NETWORKS

### A1. Examples of simple combining networks

Figures A1 and A2 illustrate examples of resistance networks suitable for combining the output signals of two or three signal generators.

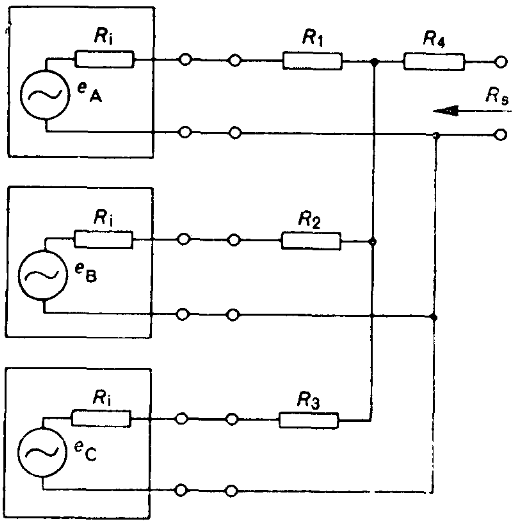


*Note.* — The source impedance $R_s$ of the network is equal to $R_i$ if:

$$R_1=R_2=R_3=\frac{R_i}{3}$$

In this case, the network attenuation is about 6 dB.

FIG. A1. — Network for combining two signals.



*Note.* — The source impedance $R_s$ of the network is equal to $R_i$ if:

$$R_1=R_2=R_3=R_4=\frac{R_i}{2}$$

In this case, the network attenuation is about 10 dB.

FIG. A2. — Network for combining three signals.

## A2. Examples of networks providing higher isolation between signal generators

Resistance networks, as shown in Figures A1 and A2, may not provide sufficient isolation between signal generators to avoid intermodulation products appearing in their output. The high isolotion networks described in Notes 1 and 2 reduce this effect.

*Notes 1.* — See IEC Publication 315-2 ( Clause 12 and Figures 1, 2 and 3 ).

2. — An example of a combining network using a hybrid ring is shown in Figure A3. The operation of this device is as follows:

The coaxial cable of the hybrid ring is cut to lengths of multiples of a quarter wavelength of the median frequency. The power from signal generator GA will then be divided equally between the termination point A ( provided the network is loaded at that point by a resistance $R_i$ ) and the resister $R_1$, the value of which is equal to $R_i$. The signals from signal generator GA at the output terminals of signal generator GB will cancel each other since the two paths differ by half a wavelength.

The power from signal generator GB is similarly divided and its signal at the output of the signal generator GA cancelled.

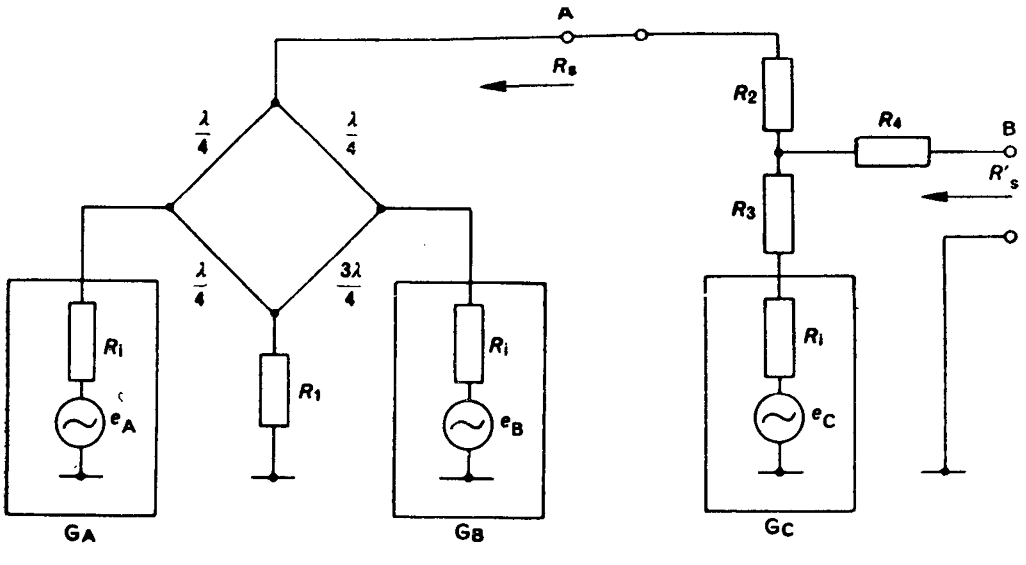
Because the coaxial cable of the hybrid ring has a relatively low quality factor ( $Q$ ), the cancellation will be effective over a wide range of frequency difference between the frequencies of the generators GA and GB.

The source impedance $R_s$ of the left-hand part of the network at point A is equal to $R_i$ ( e.g. 50 Ω ) if the characteristic impendance of the cable is $R_i\sqrt{2}$ ( e.g. 71 Ω ).

If, for certain measurements, a wanted signal in combination with two unwanted signals is needed, the third generator, Gc, supplying the wanted signal should be connected to point A by means of the combining network shown in the right-hand part of Figure A3.

The source impedance $R'_s$ of the complete network at point B is equal to $R_i$ ( e.g. 50 Ω ) :

$$R_2=R_3=R_4=\frac{R_i}{3}$$



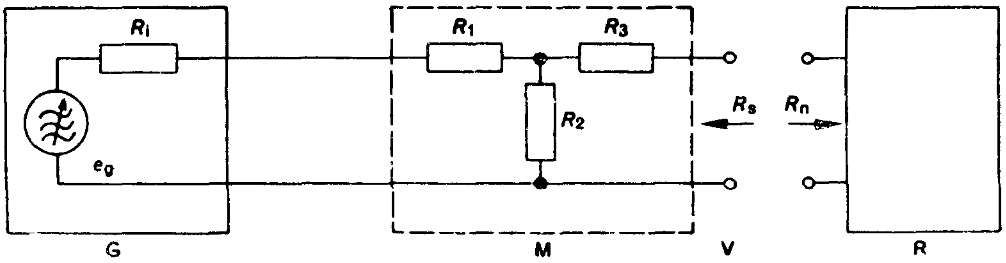
GA and GB = signal generators

Gc = additional signal generator, when required

FIG. A3. — Example of combining network using a hybrid ring.

## A3. Example of an input-signal source matching network

Other examples of such networks are given in Clause 45 of IEC Publication 315-1.



G = radio-frequency signal generator

M = matching network

R = receiver

$$R_2 = \frac{2\sqrt{N R_i R_n}}{N-1}$$

$$R_1 = R_i\left(\frac{N+1}{N-1}\right) - R_2$$

$$R_3 = R_n\left(\frac{N+1}{N-1}\right) - R_2$$

where $N$ is the required power loss ratio

FIG. A4. — Example of a matching network.

# APPENDIX B

## RECOMMENDED CHARACTERISTICS OF THE MEASURING EQUIPMENT AND ITS METHODS OF TEST

### B1. Method for testing the intermodulation characteristics of the signal generators

The intermodulation in the signal generators may be tested by the following procedure:

Insert a variable attenuator between the combining network and the receiver under test. Increase the attenuation in steps of 1 dB and increase the output voltages of the generators by the same amounts, thus maintaining the original signal level at the input to the receiver.

Since the intermodulation products in the output should remian constant, any increase is caused by intermodulation in the signal generators.

### B2. Mothod of testing signal generator noise

The measurement of certain characteristics, for example, adjacent channel selectivity, can be erroneous when a signal generator having a high spectral noise constant is used.

At frequencies below 200 MHz, a crystal filter having at least 20 dB rejection at the adjacent channel can be connected at the output of the generator under test as a means of assessing whether a result is influenced by signal generator noise.

# APPENDIX C

## RAYLEIGH FADING SIMULATOR

### C1. General characteristics of a Rayleigh fading simulator

A Rayleigh fading simulator is a test apparatus which will modulate a radio-frequency signal in a manner which simulates the fast variation of signals encountered in the mobile services. The following three characteristics of a fading simulator must be known:

*a)* the phase distribution of the fading-modulated signal;

*b)* the level distribution of the envelope of the modulated signal;

*c)* the mean rate at which the envelope of the modulated signal crosses a given level (in one direction).

Measurements using Rayleigh fading simulators are meaningful only if the ressults which are obtained depend only slightly on the simulators used. To ensure this, it is necessary that the Rayleigh simulator has the following characteristics:

1) The phase of the modulated radio-frequency signal shall have a density distribution within ± 20% of $1/2\pi$ with reference to the phase of the radio-frequency input signal over the range of $-\pi$ to $+\pi$ radians.

2) The cumulative distribution of the envelope of the modulated radio-frequency signal shall be within ±2 dB of a cumulative Rayleigh distribution over a range of +8 dB to −32 dB referred to the r.m.s. value of the modulated radio-frequency signal. According to the Rayleigh law, $P(\Gamma)$ is the probability that the envelope of the modulated radio-frequency is equal to or less than the value of $x$ as calculated below:

$$P(\Gamma) = 1 - e^{-\Gamma^2} \qquad (1)$$

where

$$\Gamma = \frac{x}{x(\text{r.m.s})} = \frac{\text{instantaneous envelope voltage}}{\text{r.m.s. voltage of the envelope}} \qquad (2)$$

3) The mean level crossing rate (in one direction), shall be within ± 20% of:

$$N\theta = \sqrt{2\pi} f_{\mathrm{m}} . \theta .\ \mathrm{e}\text{-}\theta^2, \text{ in s}^{-1} \qquad (3)$$

for $\theta$ varying from +5 dB to −25 dB with $f_{\mathrm{m}} = v/\lambda$ (4)

where

$v$ is the vehicle velocity, in metres/second
$\lambda$ is wavelength of signal, in metres

$$\theta = \frac{y}{y(\text{r.m.s})} = \frac{\text{voltage level for envelope crossing rate determination}}{\text{r.m.s. voltage of the envelope}} \qquad (5)$$

The r.m.s. will have large short-term variations. Therefore to reduce the uncertainty, its value should be determined over a sufficienty long period.

*Note.* — The median value of the envelope is 1·6 dB less than the r.m.s. value.

For an example of a Rayleigh fading simulator see Figure C1.

## C2. Performance verification of a Rayleigh fading simulator

### C2.1 *Principle of verification*

This verification applies to each of the parameters previously defined under Items *a)*, *b)* and *c)* of Clause C1. It consists of:

1) comparing the values obtained at the simulator output with the theoretical values corresponding to phase distribution, envelope distribution and mean level crossing rate;

2) ensuring that the corresponding deviations do not exceed the permitted tolerance.

### C2.2 *Equipment used*

A fast logarithmic radio-frequency selective measuring device, a phase meter, and means for analyzing a distribution are required to carry out the performance verification. An example of equipment for doing this is illustrated in Figure C2.

The requirements for the equipment are:

- — The baseband output of the logarithmic radio-frequency measuring device shall have a flat response from 0 to 3 000 Hz and an output range of 40 dB. The output of the radio-frequency selective measuring device shall be compatible with the input range of the A/D converter.
- — The A/D converter shall have 8-bit encoding and have a conversion time no greater than 80 ms.
- — The memory should be capable of storing at least 32 000 8-bit words (Bytes) at the rate generated by the A/D converter. Although this memory size will not hold all of the information generated in one measurement, statistical significance will not be lost if the samples are taken in several segments, provided that the sum of the samples in the segments is equal to the required number of samples.
- — The baseband output of the phase meter shall have a flat response from 0 to 3 000 Hz and be able to make accurate phase measurement over an amplitude range of at least 40 dB.
- — The processor should be capable of storing the output of the A/D converter in the memory and then taking the information from the memory and processing it.

*Notes 1.* — If the output of the A/D converter is processed in real time to provide an address to a memory position that can be made to correspond to a level or phase, then the memory position content can be increased by 1 each time that it is addressed. This method requires only 256 16-bit words of memory for the amplitude or phase measurement and reduces the time needed to process the data.

*2.* — For the crossing rate measurement, the same process can be used. In this case, however, seven analog comparators, each connecting to a 16-bit word of memory, would be required.

### C2.3 *Method of measurement*

#### C2.3.1 *Method of measurement for phase distribution*

*Note.* — To achieve statistical significance, this measurement requires that 64 000 phase samples be used to verify the phase performance of the Rayleigh fading simulator.

*a)* Connect the equipment as illustrated in Figure C2.

*b)* Adjust the frequency of the clock of the A/D converter to 40 times $f_m$, in hertz.

*c)* Adjust the frequency of the radio-frequency signal generator to the frequency band of interest and note the frequency.

*Note.* — The Rayleigh fading simulator should be verified at a radio frequency which is within 20% of the frequency of the receiver being measured.

*d)* Adjust the velocity control of the Rayleigh fading simulator ( or bandwidth of the noise lowpass filters) according to equation (4) for a specified velocity of the application of interest and note the velocity.

The specified velocities are:

— 10 km/h, 20 km/h, 50 km/h and 100 km/h for modile application;

— 1 km/h, 2 km/h, 5 km/h and 10 km/h for portable application.

If the velocity control is adjustable in discrete steps, it shall be set to within 20% of the specified velocity.

*e)* Adjust the radio-frequency input level to the Rayleigh fading simulator to the value specified by the manufacturer.

*f)* Clear the memory, and reset the sample counter (or clock).

*g)* Run the measurement for 64 000 samples, and store the values for the samples in the memory.

*h)* Process the information in the memory to detemine the number of samples that occurred in each 10 degree phase increment, and record the results.

*i)* Repeat Steps *d)* to *h)* for the other specified velocities.

C2.3.2 *Presentation of results*

*a)* Record the radio frequency noted in Step *c)* and the velocity in Step *d)* of Sub-clause C2.3.1.

*b)* Make a table of the phase angles and the number of samples in each of the 36 ten-degree increments for each velocity recorded in Step *d)* of Sub-clause C2.3.1.

*c)* If the number of samples in each class lies between 1 422 and 2 134, record that the simulator complies with this IEC standard for the phase distribution at the specified velocity and radio freqency.

C2.3.3 *Method of measurement for crossing rate and envelope distribution*

*Note.* — To achieve statistical significance, the crossing rate measurement requires that 128 000 samples of the envelope be used to verify the crossing rate performance of the Rayleigh fading simulator. The same samples may be used to measure the envelope distribution of the Rayleigh fading simulator.

*a)* Connect the equipment as illustrated in Figure C2.

*b)* Adjust the conversion rate of the A/D converter to 128 times $f_m$, in hertz.

*c)* Adjust the frequency of the radio-frequency signal generator to the frequency band of interest, and note the frequency.

*Note.* — The Rayleigh fading simulator should be verified at a radio frequency which is within 20% of the frequency of the receiver being measured.

*d)* Adjust the velocity control of the Rayleigh fading simulator (or bandwidth of the noise lowpass filters) according to equation (4) for a specified velocity of the application of interest and note the velocity.

The specified velocities are:

— 10 km/h, 20 km/h, 50 km/h and 100 km/h for mobile application;

— 1 km/h, 2 km/h, 5 km/h and 10 km/h for portable application.

If the velocity control is adjustable in discrete steps it shall be set to within ±20% of the specified velocity.

*e)* Adjust the radio-frequency input level to the Rayleigh fading simulator to the value specified by the manufacturer.

*f)* Clear the memory, and reset the sample counter (or clock).

*g)* Run the measurement for 128 000 samples, and store the value of the samples in the memory.

*h)* Process the information in the memory to determine the cumulative distribution of the samples. It is recommended that each class have width of 1 dB.

*i)* Process the information in the memory to determine the number of level crossings (one direction) of the envelope for each level ($-25, -20, -15, -10, -5, 0$ and $+5$ dB) referred to the r.m.s. value of the signal envelope.

*j)* Repeat Steps *d)* to *i)* for the other specified velocities.

C2.3.4 *Presentation of results for envelope distribution*

*a)* Record the frequency noted in Step *c*) and the velocity noted in Step *d*) of Sub-clause C2.3.3.

*b)* Plot the cumulative distribution determined in Step *h)* of Sub-clause C2.3.3 on Rayleigh graph paper, or make a table of $\Gamma$ in decibels and the cumulative number of samples.

*c)* Record the verification that the simulator complies with this IEC standard for the cumulative envelope distribution at the specified velocity and radio-frequency if the value lies within 2 dB of the corresponding value defined by equation (1) or if the cumulative number of samples is within the range shown in Table CI.

C2.3.5 *Presentation of results for level crossing rate*

*a)* Make a table of the envelope levels, and the number of crossings for each level and for each velocity observed in Step *d)* of Sub-clause C2.3.3.

*b)* Record the verification that the simulator complies with IEC standards for level crossing rate if the number of crossings for each level is within the range shown in Table CII, for each specified velocity and radio-frequency.

### TABLE CI

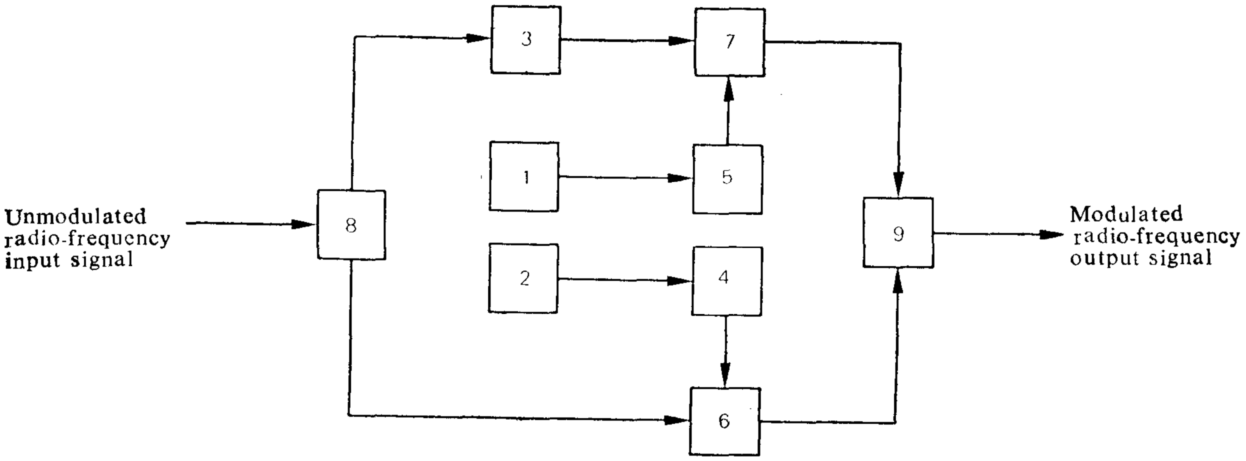
*Limits for the cumulative number of samples at each value of decibels*

| Level (dB) | Lower limit | Expected value | Upper limit |
|---|---|---|---|
| —32 | 51 | 81 | 128 |
| —31 | 64 | 102 | 161 |
| —30 | 81 | 128 | 203 |
| —29 | 102 | 161 | 255 |
| —28 | 128 | 203 | 321 |
| —27 | 161 | 255 | 404 |
| —26 | 203 | 321 | 509 |
| —25 | 255 | 404 | 640 |
| —24 | 321 | 509 | 805 |
| —23 | 404 | 640 | 1 013 |
| —22 | 509 | 805 | 1 274 |
| —21 | 640 | 1 013 | 1 601 |
| —20 | 805 | 1 274 | 2 013 |
| —19 | 1 013 | 1 601 | 2 529 |
| —18 | 1 274 | 2 013 | 3 175 |
| —17 | 1 601 | 2 529 | 3 984 |
| —16 | 2 013 | 3 175 | 4 996 |
| —15 | 2 529 | 3 984 | 6 257 |
| —14 | 3 175 | 4 996 | 7 827 |
| —13 | 3 984 | 6 257 | 9 774 |
| —12 | 4 996 | 7 827 | 12 181 |
| —11 | 6 257 | 9 774 | 15 141 |
| —10 | 7 827 | 12 181 | 18 761 |
| —9 | 9 774 | 15 141 | 23 153 |
| —8 | 12 181 | 18 761 | 28 432 |
| —7 | 15 141 | 23 153 | 34 702 |
| —6 | 18 761 | 28 432 | 42 036 |
| —5 | 23 153 | 34 702 | 50 456 |
| —4 | 28 432 | 42 036 | 59 893 |
| —3 | 34 702 | 50 456 | 70 159 |
| —2 | 42 036 | 59 893 | 80 911 |
| —1 | 50 456 | 70 159 | 91 653 |
| 0 | 59 893 | 80 911 | 101 764 |
| 1 | 70 159 | 91 653 | 110 595 |
| 2 | 80 911 | 101 764 | 117 617 |
| 3 | 91 653 | 110 595 | 122 582 |
| 4 | 101 764 | 117 617 | 125 611 |
| 5 | 110 595 | 122 582 | 127 148 |
| 6 | 117 617 | 125 611 | 127 767 |
| 7 | 122 582 | 127 148 | 127 955 |
| 8 | 125 611 | 127 767 | 127 994 |

### TABLE CII

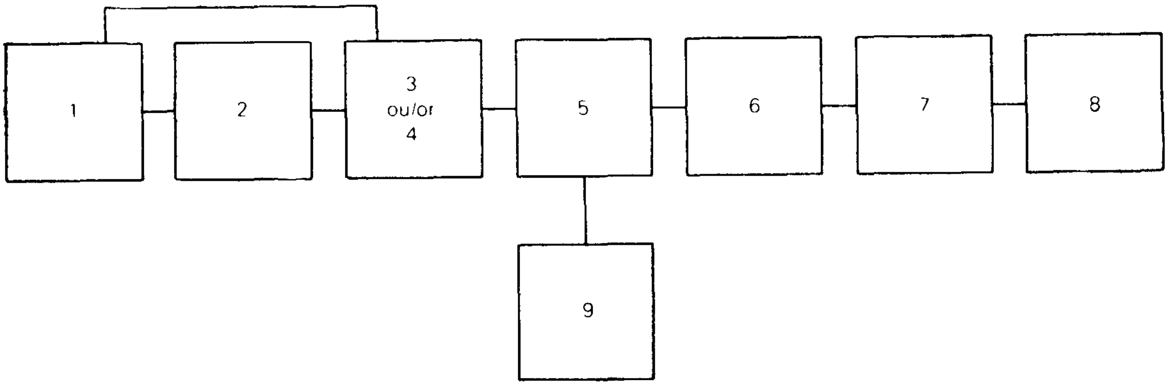
*Limit for the number of level crossings in the measurements*

| Level (dB) | Expected rate (*f*m) | Lower limit | Expected value | Upper limit |
|---|---|---|---|---|
| - 25 | 0.14 | 112 | 141 | 169 |
| - 20 | 0.25 | 199 | 248 | 298 |
| - 15 | 0.43 | 345 | 432 | 518 |
| - 10 | 0.72 | 574 | 717 | 861 |
| - 5 | 1.02 | 822 | 1 027 | 1 233 |
| 0 | 0.92 | 738 | 922 | 1 107 |
| + 5 | 0.19 | 151 | 189 | 226 |


Unmodulated radio-frequency input signal
8
3
1
2
7
5
4
6
9
Modulated radio-frequency output signal

1,2 = Gaussian noise generators
2 = 90° phase shifter
4,5 = low-pass filters
6,7 = balanced mixers
8 = power divider
9 = hybrid

FIG. C1. — Example of a Rayleigh fading simulator.



1 = radio-frequency signal generator
2 = Rayleigh fading simulator
3 = phase meter
4 = logarithmic, radio-frequency, selective measuring device
5 = A/D converter
6 = memory (if necessary)
7 = processor
8 = output device
9 = variable clock

*Note.* — If the simulator (2) does not have a zero velocity setting, it should be bypassed and the output of the generator (1) should be adjusted to allow for its attenuation.

FIG. C2. — Example of measuring arrangement for evaluating a Rayleigh fading simulator.

# APPENDIX D

## INTERMODULATION RESPONSE

### D1. Intermodulation response

Intermodulation responses corresponding to the intermediate frequency are not significant in this class of equipment.

Unwanted signal frequencies which may produce an intermodulation response are related to the wanted signal frequency as follows:

D1.1 *Second-order relationship*

$$f_W = f_r \pm f_n$$

*Note.* — Commonly used frequency relationships include:

$f_n = f_w + \Delta f$ $\qquad$ $f_n = f_w - \Delta f$

or

$f_r = 2f_w + \Delta f$ $\qquad$ $f_r = 2f_w - \Delta f$

D1.2 *Third-order relationship*

$$f_W = 2f_n \pm f_r$$

*Note.* — Commonly used frequency relationships include:

$f_n = f_w + \Delta f$ $\qquad$ $f_n = f_w - \Delta f$

or

$f_r = f_w + 2\Delta f$ $\qquad$ $f_r = f_w - 2\Delta f$

D1.3 *Fifth-order relationship*

$$f_w = 3f_n \pm 2f_r$$

*Note.* — Commonly used signal frequency relationships include:

$f_n = f_w + \Delta f$ $\qquad$ $f_n = f_w - \Delta f$

or

$f_r = f_w + 1.5\Delta f$ $\qquad$ $fr = f_w - 1.5\Delta f$

where

$f_w$ is the frequency of the wanted signal
$f_n$ is the frequency of the nearer unwanted signal
$fr$ is the frequency of the more remote unwanted signal
$\Delta f$ is the frequency difference between the wanted signal and the nearer unwanted signal

Other intermodulation orders exist. However, selection of a reasonable number of frequencies $f_n$ and $f_r$ is generally sufficient to describe the performance of the equipment considered in this standard with respect to intermodulation.

# APPENDIX E

## GUIDE FOR THE CONSTRUCTION OF A 30 m RADIATION TEST SITE FOR EQUIPMENT RECEIVING RADIO-FREQUENCY ELECTROMAGNETIC ENERGY

The equipment parameter measurements applicable to this test site are all measurements pertaining to received radio-frequency energy, for example, receiver radiation sensitivity.

### E1. Test site characteristics

| | *Limits* |
|---|---|
| Useful frequency range: | 25 MHz to 1 000 MHz |
| Nominal site attenuation: | 20 dB to 46 dB for 25 MHz<br>52 dB to 78 dB for 1 000 MHz |

*Note.* — The nominal attenuation of the test site for a half-wave dipole is 26 dB for 25 MHz and 58 dB for 1 000 MHz. The actual attenuation may vary due to ground reflections.

| | |
|---|---|
| Equipment size limits: | 6 m maximum, excluding the antenna |
| Radiation angle limits: | Limits only apply to the horizontal plane |

See Appendix H for tests using an alternative mounting arrangement.

### E2. Radiation test site

The radiation test site shall be on level ground with uniform electrical characteristics and be free from reflecting objects over as wide an area as is practical to minimize errors in the test results.

The distance between the vertical axis through the centre of the antenna of the equipment under test and the vertical axis through the centre of the transmitting antenna shall be 30 m.

The minimum boundary of the test site shall be an ellipse having a major axis equal to 60 m and a minor axis equal to 52 m. The equipment under test and the transmitting antenna shall be located at the foci.

No extraneous conducting objects having any dimension in excess of 15 cm for measurements over the frequency range of 25 MHz to 300 MHz, or 5 cm for measurements over the frequency range of 300 MHz to 1 GHz, shall be in the immediate vicinity of either the equipment under test or the transmitting antenna.

Care shall be taken to ensure that the extraneous electromagnetic field do not affect the accuracy of the test results.

All test equipment shall preferably be powered by batteries. If the equipment is powered from the mains, each of the mains supply cables shall be provied with a suitable radio-frequency filter. The cable connecting the filter and the measuring equipment shall be screened and shall be as short as possible. The cable connecting the filter and the supply mains shall be either screened and be at ground level, or shall be buried to a depth of approximately 30 cm.

### E3. Position of the equipment under test (see Figure E1).

The equipment in its cabinet or housing in which it normally operates shall be placed on a horizontal platform, the upper side of which is 1.50 m above the ground. This platform and its support shall be made of non-conducting material.

For equipment having an integral antenna, place the equipment on the platform in a position which is closest to its position in normal use.

For equipment having a rigid external integral antenna, mount the equipment so that the antenna is in a vertical position.

For equipment having a non-rigid external integral antenna, mount the antenna vertically with a non-conducting support.

It shall be possible to rotate the equipment about the vertical axis through the integral antenna. It is recommended that a platform in the form of a turntable, preferably remotely controlled, be used for this purpose.

For information on the use of alternative mounting arrangements on this test site for equipment which is hand-held or carried on the person while in normal use, see Appendix H.

### E4. Radio-frequency signal generator

The well-shielded radio-frequency signal generator, with a combining network and associated output cable, shall be placed in a position that will not affect the accuracy of the test results, and shall be connected to and matched to the transmitting antenna.

### E5. Selective measuring device

The selective measuring device (4) may be either a frequency selective voltmeter, a spectrum analyzer, or a calibrated field-strength meter.

### E6. Step attenuator

A step attenuator (5) shall be placed at the output of the radio-frequency signal generator (1). It should have a range of 80 dB in 1 dB steps.

### E7. Encoder

The encoder (7) shall be able to modulate the radio-frequency signal generator (1) with the standard coded test signal to the deviation specified by the manufacturer.

### E8. Transmitting antenna

The transmitting antenna (2) shall be suitable for the radiation of linearly polarized waves. It may consist of a half-wave dipole, but for practical reasons a more complex antenna having high directivity and broad bandwidth is preferred. The transmitting antenna shall be mounted at the end of a horizontal boom supported by a vertical pole, both made of non-conducting material. The boom shall project at least 1 m from the vertical pole in the direction of the equipment under test and shall be arranged so that the centre of the antenna is $3 \pm 0{\cdot}2$ m above the ground. The mounting shall permit the antenna to be positioned for the the same polarization as that of the receiver's antenna. The cable from the antenna should be routed along the horizontal boom and the vertical pole.

At some frequencies, appreciable variation of signal level occurs for small changes of antenna height due to ground reflections. Where this occurs, the transmitting antenna should be moved up or down by an amount that will place the antenna in a region of small height sensitivity and make the test site calibration less dependent upon small changes in antenna position.

### E9. Calibration antenna

The calibration antenna (3) replaces the equipment under test during calibration of the test site (see Figure Ela). The calibration antenna shall be an antenna of suitable dimensions for which the available power output has been calibrated in field strength. The centre of the calibration antenna will be located so that this point coincides with the centre of the integral antenna of the equipment under test. The antenna, including the cable, shall be matched to the input impedance of the selective measuring device. At frequencies below about 60 MHz, the above condition may be impossible to achieve when the antenna is arranged for vertical polarization. In this case, the lower end of the antenna should be placed 0.3 m above the ground and the equipment under test shall be positioned to satisfy the conditon above.

### E10. Method of calibrating the test site

E10.1 Connect the equipment as illustrated in Figure Ela and described in Clauses E8 and E9 with the transmitting antenna oriented to provide the polarization intended for the receiver under test.

E10.2 Adjust the frequency of the radio-frequency signal generator (1) to the operating frequency of the receiver.

E10.3 Tune the selective measuring device to the operating frequency of the radio-frequency signal generator (1).

E10.4 Adjust the output of the radio-frequency signal generator (1) to produce a reading of 100$\mu$V/m [40 dB ($\mu$V/m)] on the selective measuring device. Record the output level of the radio-frequency signal generator (1), $Uy$, in $\mu$V with attenuator (5) set to 20 dB.

*Note.* — The calibration is only valid for the frequency, antenna, polarization and antenna position used in the calibration procedure. If any of these change, the test site should be recalibrated.

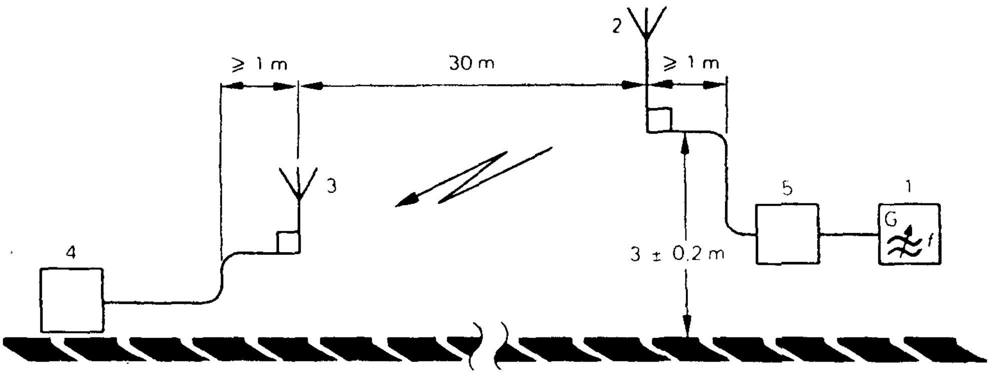


FIG. E1a.

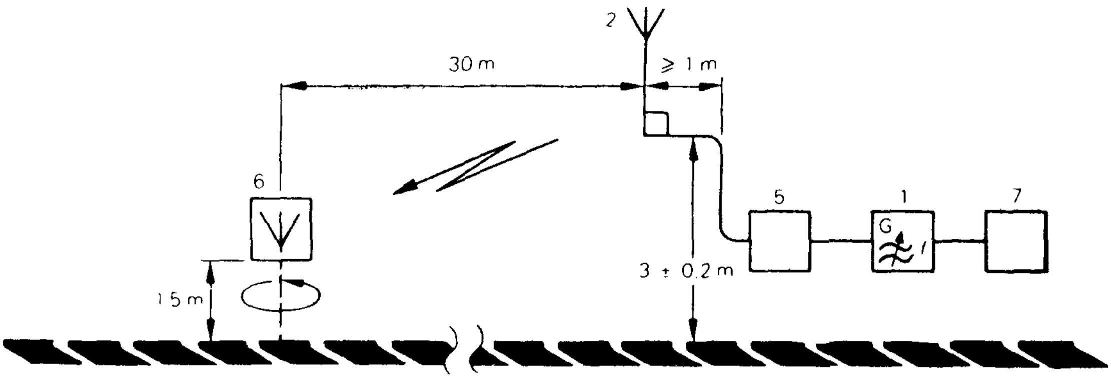


FIG. E1b.

1 = radio-frequency signal generator
2 = transmitting antenna
3 = calibration antenna
4 = selective measuring device
5 = 80 dB step attenuator, 1 dB steps
6 = receiver under test
7 = encoder

Care should be taken to ensure that the field in the vicinity of the receiver under test is not disturbed by the test equipment.

FIG. E1. — Measuring arrangement for receivers on a radiation test site (30 m).

# APPENDIX F

## ACCURACY AND DISPERSION OF METHODS OF MEASUREMENTS AND COMPLIANCE TESTS FOR SENSITIVITY (DATA AND SELECTIVE CALLING) AND DEGRADATION MEASUREMENTS (DATA AND SELECTIVE CALLING)

### F1. Introduction

This discussion will show, by analysis of examples, the underlying basis for determining the accuracy and dispersion for the methods of measurement and compliance tests used in this standard. The examples of error ratio curves selected are typical for receiver-decoders that will be measured using the methods in this standard.

The methods of measurement and compliance tests have been designed to provide the desired degree of accuracy and dispersion for equipments that have error ratio versus input signal level curves that have significantly less slope than the examples used in this discussion.

The analysis given in this appendix will allow one to use other examples of error ratio curves to evaluate the methods of measurement or compliance tests used in this standard.

In this standard, there are measurements of receiver r.f. parameters for several types of signals each having a standardized reference error ratio. The r.f. parameters fall into three classes: sensitivity, sensitivity reduction under multipath propagation conditions and degradation. In this appendix sensitivity reduction under multipath propagation conditions will be referred to as fading.

Sensitivity is the level of r.f. input signal required to produce the reference error ratio.

In this standard, the fading measurements are made using a Rayleigh fading simulator. However, most of the measurements are made in the *static* condition and in this appendix, unless otherwise stated, the static condition is implied.

The fading margin is the ratio of r.f. input signal level (static) required to produce the reference error ratio to the r.f. input signal level (faded) required to produce the reference error ratio.

In the degradation measurements, the requirement is to find the level of the unwanted input signal that causes a wanted input signal which is 3 dB in excess of the reference sensitivity that will produce the reference error ratio.

Different methods of measurements are used for the different signals. The two methods of measurement used in this standard are named the up/down method and the straddle method. A summary of the types of parameters, signals, the reference error ratio and the method of measurement used are shown in Table F1.

*Note.* — In the title of some of the figures the word 'bit' has been used for *bit stream* and 'character' has been used for *charcter string*. The word 'fading' has been used for *sensitivity (fading)*.

TABLE F1

| Receiver parameter | Type of signal | Reference error ratio | Method of measurement used |
|---|---|---|---|
| Sensitivity | Selective calling | 0·20[1] | Up/down[2] |
| Sensitivity | Data (bit stream) | 0.01 | Straddle |
| Sensitivity | Data (character string) | 0.01 | Straddle |
| Sensitivity | Data (message) | 0.20 | Up/down[2] |
| Sensitivity (fading) | Selective calling | 0.20[1] | Up/down[2] |
| Sensitivity (fading) | Data (bit stream) | 0.01 | Straddle |
| Sensitivity (fading) | Data (character string) | 0.01 | Straddle |
| Sensitivity (fading) | Data (message) | 0.20 | Up/down[2] |
| Degradation | Selective calling | 0.20[1] | Up/down[2] |
| Degradation | Data (bit stream) | 0.01 | Straddle |
| Degradation | Data (character string) | 0·01 | Straddle |
| Degradation | Data (message) | 0.20 | Up/down[2] |

[1] Selective calling uses the reference of 80% calling probability. For this discussion, the selective calling reference error ratio is 1 – 0.80 or 0.20.

[2] The method of measurement for messages used in this standard is based on the up/down method. This method seeks a signal level of wanted or unwanted signals so that the message sequence will have an error ratio of 50%.

The relationship between the number of messages in a sequence and the error ratio for the sequence is:

$$(1 - P_m)^N = 0{\cdot}5$$

where

$P_m$ is the message error rate of the message sequence;
$N$ is the number of messages in each sequence.

For example, for a $Pm$ of 0.2, $N$ is very nearly 3, which is used in the message measurements. The up/down method of measurement assumes that the errors occur independently from one message to the next, which is indeed the case. However, this method is not used for bit stream or character string measurements, because for these, the assumption does not always hold.

It should be noted that measurements of a radio-frequency parameter, for example reference sensitivity on the same receiver-decoder for bit stream, character string or message, will probably not give the same result.

## F2. Measurement and compliance test

In this standard there are two types of methods of measurement. Both types are included because they serve different purposes.

### F2.1 *Measurement*

The first type of measurement measures the parameter which is the input signal level or the unwanted signal level that produces the reference error ratio. Since this method provides an estimate of the parameter, it is a two-sided test and usually requires a longer measurement than the compliance test. This method of measurement in this discussion is referred to as a method of *measurement*.

### F2.2 *Compliance test*

The second type of measurement is the compliance test which only determines if the error ratio is greater or smaller than the reference error ratio for a specified level of input signal and unwanted signal (s). This is a one-sided test and in many cases can be performed in less time. An important characteristic of a compliance test method is its risk curve (see F8.4). The concept of the risk curve has a correspondence to the concept of dispersion for methods of measurement.

### F3. **Dispersion**

Dispersion of a measurement is characterized by a probability distribution of the results of the measurement that can be expected when the measurement is performed many times on the same equipment under the same conditions.

### F3.1 *Definition of dispersion*

Dispersion varies with test equipment, with operator and, in the measurement of selective call and data receivers, with the statistical process used in the measurement. In this appendix, only the latter is discussed for measuring sensitivity, fading and degradation.

The measurements will produce values (estimates) which have a probability distribution that has a bell shape for units of input signal level in decibels. Since the probability distribution can be different for each receiver-decoder measured, the dispersion is defined as the range of input signal levels from the level where the cumulative probability distribution equals 0.05 probability to where it equals 0.95 probability (e.g. – 1.2 to 0.9 dB).

For compliance tests, dispersion is defined as the difference between the receiver-decoder parameter that has a 0.95 probability of passing and one that has a 0.05 probability of failing (see F 8.4).

### F3.2 *Magnitude of dispersion*

The design goals for the methods of measurement and compliance test methods in this standard are to have a dispersion and risk of:

± 1 dB or less for sensitivity,

± 2 dB or less for degradation (e.g. selectivity or intermodulation),

± 2 dB or less for fading.

This was done by assuming the lowest slope of the error ratio curves generally experienced in current receiver-decoders and by selecting the number of elements (tones, bits, characters or messages) used in the method of measurement or compliance test method.

While the examples used in this discussion are typical, they have considerable margin to the above goals in their dispersion and risk. The methods of measurement and compliance test methods have been designed with this in mind, as there may be receiver-decoders measured that have error ratio curves that are significantly different from those in the examples.

The number of elements selected for the methods of measurement or compliance test methods have been reduced to the minimum, consistent with the above goals.

While there are many useful methods available for making these measurements and compliance tests, the methods chosen to be standardized for this standard will produce the desired dispersion and risk.

## F4. Accuracy

Accuracy for methods of measurement, in this appendix, is characterized by the difference between the average estimate obtained from the measurement and the theoretical value that one would expect to obtain. For example, if the theoretical value for a method of measurement is zero dB and the average of the estimates obtained from the method of measurement is $-0.08$ dB, the accuracy of the method of measurement is $-0.08$ dB. Accuracy should not be confused with the range of dispersion. A method of measurement could have a small dispersion and a high inaccuracy or the opposite. Ideally, the method of measurement should have low values for both dispersion and accuracy.

Accuracy for compliance test methods is the difference between the relative input signal level that produces 0.5 probability of passing and the theoretical value.

## F5. Shapes of error ratio curves

Important factors that determine the dispersion of a method of measerement or the risk of compliance test methods are the reference error ratio, the shape of the error ratio curve of the equipment under test and the number of elements used in the method of measurement or compliance test method.

The shape of the error ratio curve for a receiver-decoder can be determined by the lengthy process of measuring the error ratio for different input signal levels and plotting the result. In this standard, it is assumed that the error ratio curve is not known to the operator except for some general bounds and is not required by the method of measurement or the compliance test method. In this appendix, however, the examples used provide a model that allows the error ratio curve to be determined for the examples which are used in this discussion.

All of the error ratio curves for the examples used in this appendix have been normalized so that zero dB is at the reference error ratio. The analysis only makes use of the shape of the error ratio curves. Receiver-decoders that require a greater signal-to-noise ratio will have their error ratio curves shifted to the right and if the required signal-to-noise ratio is less, the error ratio curves will be shifted to the left.

### F5.1 *Shapes of bit stream error ratio curves*

### F5.1.1 *For sensitivity measurements*

For data ( bit stream ), common examples of error ratio functions ( *see* page 406 of reference [1]* used for receiver-decoders ( static ) are:

$$Err_{\text{bit}} = 0.5 \left[ 1 - erf\left( \sqrt{C/A} \right) \right] \qquad (1)$$

where

$Err_{\text{bit}}$ is the bit error ratio

$erf$ is the error function

$C$ is the ratio of the carrier to noise power

$A = 1$ for ideal coherent PSK (antipodal signalling)

$A = 2$ for coherent FSK (orthogonal signalling)

The value of $A$ varies with the modulation system used but it does not affect the shape of the error ratio curve. See curve 1 of Figure F1.

Other examples of error ratio function are (*see* page 406 of reference [1]):

$$Err_{\text{bit}} = 0.5\, exp\,(-C/A) \qquad (2)$$

---

*The figures in square brackets refer to Clause F9.

where
$C$ is the ratio of the carrier to noise power
$A = 1$ for differentially coherent PSK
$A = 2$ for non-coherent FSK

See curve 2 of Figure F1. It is also assumed in this appendix that the carrier power is directly proportional to the input signal level.

Error ratio curves are most often presented in the format of log error ratio versus input signal level in dB.

Error ratio curves measured on receiver-decoders may differ from those in Figure F1, but most will be sufficiently similar to this model. Since the curve for equation 1 has the least slope in the region of 0.01 error ratio, it will be used as the bit error ratio curve for the remainder of this discussion. The error ratio curve of a receiver-decoder is not known by the experimenter and can vary significantly from this example. The dispersion and risk obtained using this error ratio curve should be about one-half that stated in F3.2 so that the methods of measurement and compliance test methods are viable for measuring receiver-decoders that have error ratio curves with slopes of about one-half that of the examples.

### F5.1.2 *For degradation measurements*

Selectivity, spurious response immunity, intermodulation response immunity and impulsive noise tolerance are degradation measurements as they measure the level of unwanted signals. In this discussion, the following model for degradation measurements will be used; it is also applicable to the compliance test methods.

In these methods of measurement, the wanted signal level is first set at the reference sensitivity without the unwanted power applied to the input of the receiver. Then the wanted signal level is increased 3 dB (twice the power) which accounts for the factor 2 in the numerator in the following equation. The same reference error ratio (the same signal-to-noise ratio) is reproduced by applying the unwanted power.

$$\text{Signal-to-noise ratio} = 2S/(N + U) \tag{3}$$

where
$S$ is the wanted signal power corresponding to the receiver-decoder reference sensitivity
$N$ is the noise power of the receiver and is assumed to be constant
$U$ is the unwanted signal power or the power of the on channel intermodulation response for spurious and intermodulation immunity measurements

$U$ is the unwanted power in the receiver (e.g. at the detector) and has been attenuated by the receiver. The input unwanted signal level recorded in the degradation measurements will be a function of the receiver attenuation and of a non-linear coefficient.

In this discussion, for selectivity, spurious response immunity and impulsive noise tolerance, it is assumed that $U$ is proportional to the input level of the unwanted signal(s). If the unwanted power is generated by an intermodulation process than $U$ may vary exponentially as a power of the unwanted signal(s). In this case, the degradation bit error ratio curve will have a steeper slope.

If the signal-to-noise ratio from equation (3) is applied to equation (1) as $C$, the result is curve 3 in Figure F1. In the graph the input signal level is $U$, so the bit error ratio increases as $U$ increases and the slope of the curve near the reference error ratio is less steep than the bit error ratio curve.

### F5.1.3 *Sensitivity measurement impact on degradation measurements and compliance tests*

Curve 3 in Figure F1 is based on the assumption that the value $S$ is replaced by $2S$ in equation (3). In the degradation method of measurement, the value of $S$ used is an estimate obtained from the sensitivity measurement and has a distribution. If the value of $S$ used is not exactly the value for the receiver-decoder sensitivity, the shape of the degradation error ratio curve will move either to the right or to the left as well to change its slope. The result of this effect is that the dispersion and risk are greater than they would be if the exact sensitivity were known and used in the degradation measurements and compliance tests.

### F5.2 *Shape of character string error ratio curves*

For characters which are composed of a number of bits, the shape of the error ratio curves is derived from the bit error ratio curve. The shape is a function of the number of bits in the character and whether error correction codes are used.

For example, curve 1 of Figure F2 is the character error ratio curve for an 8-bit character with no error correction and curve 2 is for a 15-bit character with one bit of error correction capability.

The main difference between bit stream and character string error ratio curves is that while the maximum error ratio for bit stream is 0.5 the maximum ratio for character string can be almost 1.0. Generally, but not always, the slope of the curve near the reference error ratio of 0.01 is steeper for character strings than for bit streams.

For the remainder of this discussion, a character of 8 bits with no error correction has been used, so the character error ratio is:

$$Err_{\text{char}} = 1-(1-Err_{\text{bit}})^8 \tag{4}$$

where $Err_{\text{bit}}$ is the bit error ratio from equation (1).

*Note.* — The equation above is correct with the assumption that the bit errors are independent. This assumption is used in this appendix. However, there are many cases where this assumption does not hold. For example, in some modulations with differential encoding (e.g. PSK modulation with differentially coherent ( detection ) bit errors occur in pairs. In this case for low bit error ratios:

$$Err_{\text{char}} = 1-(1-Err_{\text{bit}}/2)^8$$

Other types of modulation, decoders and propagation which tend to have the bit errors correlated may have different relationships which would change the shape of the error ratio curves used in the examples in this appendix.

Degradation curve 3 of Figure F2 was derived using the same procedure (see F5.1.1) as for degradation curve 3 of Figure F1.

Codes that use more bits per character and use error correcting codes generally will have steeper slopes near the reference error ratio.

### F5.3 *Shape of message error ratio curves*

Messages can take on many configurations and therefore the error ratio curves will vary a great deal. The example chosen for this discussion consists of 128 bits ( e.g. 16 8-bit characters ) with no error correction and is shown in Figure F3. While the length of the message is not uncommon, most systems would have some form of error control which generally would make the slope of the error ratio curve greater near the reference error ratio of 0.2. The curve of $Err_{\text{mass}}$ is derived from the bit error ratio curve given in curve 1 of Figure F1 using the following function:

$$Err_{\text{mess}} = 1 - (1 - Err_{\text{bit}})^{128} \qquad (5)$$

where $Err_{\text{bit}}$ is the bit error ratio from equation (1).

For this example, a 0.2 message error ratio corresponds to a 0.0017 bit error ratio.

*Note.* — The equation above is correct with the assumption that the bit errors are independent. This assumption is used in this appendix. However, there are many cases where this assumption does not hold. For example, in some modulations with differential encoding ( e. g. PSK modulation with differentially coherent detection ) bit errors occur in pairs. In this case for low bit error ratios:

$$Err_{\text{mess}} = 1 - ( 1 - Err_{\text{bit}} /2 )^{128}$$

Other types of modulation, decoders and propagation which tend to have the bit errors correlated may have different relation ships which would change the shape of the error ratio curves used in the examples in this appendix.

Degradation curve 2 of Figure F3 was derived using the same procedures ( see F5.1.1 ) as for degradation curve 3 of Figure F1.

Codes that use more bits in the message and use error correcting codes generally will have steeper slopes near the reference message error ratio of 0.2.

### F5.4 *Shape of selective calling error ratio curves*

#### F5.4.1 *For digital modulation*

When the selective call transmission has a digital form, the results will be very similar to that of message ( see above ) and for this discussion will be assumed to be the same for both sensitivity and degradation measurements.

#### F5.4.2 *For analog modulation*

For AM and SSB, when the selective call transmission consists of several audio frequency tones transmitted simultaneously or in sequence, the selective calling error ratio curve may be similar in shape to the character error ratio curve. For FM and PM, the error ratio curves may have a considerably steeper slope. While the error ratio of each tone detector may have a shape not unlike that of equation (1), many designs have the tone detect level located on the steep portion of the FM threshold curve ( i.e. below the threshold knee ). In this case, the signal-to-noise ratio $C$ in equation (1) may vary much faster than the input signal level and the selective calling error ratio may vary from 0.9 to 0.1 for a one or two dB change in input level.

### F5.5 *Shape of error ratio curves for fading signals*

The measurement of sensitivity fading uses an input signal that is produced by a Rayleigh fading simulator ( *see* appendix C ). The bit stream, character string and message error ratio curves that result from using this signal differ considerably from those obtained from the static condition.

#### F5.5.1 *Shape of bit stream error ratio curve*

For this discussion, the error ratio versus the mean carrier to noise power ratio function that models non-coherent FSK ( *see* page 407 of reference [1] ) will be used and is:

$$Err_{\text{bit}} = 1/ ( 2 + \overline{C}/A ) \qquad (6)$$

where

$\overline{C}$ is the mean carrier to noise power ratio
$A$ = 1 for differentially coherent PSK
$A$ = 2 for non-coherent FSK

A curve of this function is shown in Figure F4, curve 1. It has been normalized to have a zero dB input signal level produce a 0.01 bit error ratio and is shown for ± 6dB about this level. Again it is assumed that the mean carrier power is proportional to the mean input signal level.

F5.5.2 *Shape of character string error ratio curve*

Using the example of a character in F5.2 applied to equation (6), the normalized curve is almost identical to the bit stream error ratio curve and is shown in Figure F4, curve 2.

F5.5.3 *Shape of message error ratio curve*

Using the example of a message in F5.3 applied to equation (6), the normalized curve for zero dB to produce 0.2 error ratio is shown in Figure F4, curve 3.

## F6. Models for the straddle method of measurement

The straddle method of measurement is used in this standard for bit stream and character string measurements of sensitivity, fading and degradation. The sensitivity and fading methods of measurement and compliance test methods have been analyzed to determine the expected dispersion and risk of the examples used. For the bit stream only, the degradation measurement has been analyzed using the assumption that the sensitivity is known. However, to simulate the degradation method of measurement as it is used, Monte Carlo simulations were used to obtain estimates of the dispersion and risk.

F6.1 *Model for bit stream sensitivity measurement*

For this discussion, a bit error ratio curve given by equation (1) is assumed and the know sensitivity is zero dB. All other input levels are referenced to zero dB. See Figure F1, curve 1.

The method of measurement says to start the measurement at an input signal level corresponding to the specified reference sensitivity. Let us assume, for example, that this starting level $L_1$ corresponds to a bit error ratio higher than 1%. The successive input signal levels $L$ ( $i = 1, 2, \ldots, n$ ) will be increased by steps of 0.5 dB. ( A similar analysis could be performed if the initial bit error ratio was lower than 1%.)

When 2 500, bits are transmitted with level $L_i$, one of the following events occurs:

- Event X: there are more than 25 bits in error. Then increase the input signal level by 0.5 dB and $L_{i+1} = L_i + 0.5$.
- Event Y: there are exactly 25 bits in error. Then the measurement is terminated ( $L_i = L_n$ ). Record the bit sensitivity as $S = L_n$. The preceding levels tested as possible values of $S$ have been $L_1, \ldots, L_i \ldots, L_n = S$ ( called "series one" ).
- Event Z: there are ( for the first time ) less than 25 bits in error. Then the measurement is terminated ( $L_i = L_n$ ). Record the bit sensitivity as $S = L_n - 0.25$ dB ( or $L_{n-1} + 0.25$ dB ). The preceding levels tested as possible values of $S$ have been ( $L_1 - 0.25$ ), ......, ( $L_i - 0.25$ ), ......, ( $L_n - 0.25 = S$ ) ( called "series two" ) but the corresponding input signal levels are 0.25 dB higher than $S$ or equal to $L_1, \ldots, L_i, \cdots, L_n$.

Event Y occurs with a probability:

$$p_Y ( S = L_i ) = \frac{2500! \; ( 1 - Err_{bit} )^{2475} \; Err_{bit}^{\;25}}{25! \; 2745!} \qquad (7)$$

where $Err_{bit}$ is the bit error ratio corresponding to level $L_i$ ( *see* Figure F1 ).

Event Z occurs with a probability:

$$p_z\ (S=L_i-0.25) = \sum_{k=0}^{k=24} \frac{2500!\ (1-Err_{bit})^{2500-k}\ Err_{bit}^{\ k}}{k!\ (2500-k)!} \tag{8}$$

where $Err_{bit}$ is the bit error ratio corresponding to level $L_i$ ( see Figure F1 ).

Obviously the probability of having event X for an input signal level equal to $L_i$ is:

$$p_x\ (L_i) = 1 - p_y\ (S=L_i) - p_z\ (S=L_i-0.25) \tag{9}$$

The probablity $p(L_i)$ that a level $L_i$ of the "series one" be recorded as the sensitivity corresponds to the probability of event Y multiplied by all the probabilities of preceding events X, i.e.:

$$p\ (S=L_i) = p_y\ (S=L_i) \times \prod_{j=1}^{j=i-1} p_x\ (S=L_1) \tag{10}$$

The probability $p(L_i-0.25)$ that a level $(L_i-0.25)$ of the "series two" be recoraed as the sensitivity corresponds to the probability of event Z multiplied by all the probabilities of preceding events X, i.e.:

$$p\ (S=L_i-0.25) = p_z\ (S=L_i-0.25) \times \prod_{j=1}^{j=i-1} p_x\ (S=L_1) \tag{11}$$

For example, the measurement starts at an input signal level $L_1=-2.8$ dB, corresponding to a bit error ratio of 0.06 ( see Figure F1 ). The probability of being at the start level is 1, and:

$$p\ (S=-2.8) = p_y\ (S=-2.8)$$
$$p\ (S=-2.55) = p_z\ (S=-2.55)$$

If events Y and Z do not occur, the level is increased by 0.5 dB and $L_2=-2.3$ dB.

Then, from equation (9) and using equations (10) and (11) alternately:

$$p\ (S=-2.3) = p_y\ (S=-2.3)\ [\ 1-p_y\ (S=-2.8)-p_z\ (S=-2.55)]$$
$$p\ (S=-2.05) = p_z\ (S=-2.05)\ [\ 1-p_y\ (S=-2.8)-p_z\ (S=-2.55)]$$

and so on.

For this example, the different values obtained are plotted in Figure F5 and the values greater than $10^{-6}$ and the cumulative probability are given in Table F2.

TABLE F2

| Value of $S$ in dB | $p_{(s)}$ | Cumulative probability $p_{(s)}$ |
|---|---|---|
| —0.8 | 0.001 15 | 0.001 15 |
| —0.55 | 0.001 45 | 0.002 60 |
| —0.3 | 0.044 14 | 0.046 74 |
| —0.05 | 0.123 93 | 0.170 67 |
| 0.2 | 0.051 53 | 0.222 20 |
| 0.45 | 0.612 96 | 0.835 16 |
| 0.7 | 0.000 62 | 0.835 78 |
| 0.95 | 0.163 49 | 0.999 27 |
| 1.2 | $<10^{-6}$ | 0.999 27 |
| 1.45 | 0.000 73 | 1.000 00 |

The results obtained for the example are related to the starting level of $-2.8$ dB and other starting levels would have slightly different results. By repeating the calculation for many starting levels ( e.g. $-3$ to $-2.5$ dB ) an envelope of $p_{(s)}$ can be plotted. This can be considered the probability distribution of $p_{(s)}$ for this example and is curve 1 in Figure F6. The accuracy for this example, at any low starting level, is $-0.014$ dB.

The cumulative probability $P_{(s)}$ is curve 2 of Figure F6 and shows that 90% of the results will be between $-0.5$ and 0.4 dB (levels for which $P_{(s)}$ equals 0.05 and 0·95) which is the dispersion for this example for any low starting level.

F6.2 *Bit stream degradation measurement*

The analysis for the degradation measurement is similar to that for the sensitivity measurement except for two items.

The first is that $U$, the unwanted signal level, is used (see F5.1.2) and, for this example, curve 3 of Figure F1 is used.

The method of measurement uses the same events X, Y and Z mentioned in F6.1 except that "input signal" is replaced by "unwanted input signal" and all the words "decrease", "increase", "subtract" and "add" are reversed.

The second is that the unwanted input signal level that results in an initial high error ratio will be high (e.g. 3.4 dB is assumed in this example) and the measurement method will progressively lower the unwanted input signal level.

The resultant probability distribution, $P$(s), for a bit stream degradation measurement is curve 3 of Figure F6. The accuracy of this example is 0.112 dB.

Curve 4 of Figure F6 is the cumulative probability of $P$(s) and shows that for this simplified model given in this example the degradation dispersion is $-0.6$ to 0.9 dB.

Curves 3 and 4, which are helpful in obtaining an understanding of the methods of measurement, are based on the simplifying assumption that the estimate of the bit sensitivity is exactly *known and used* in the measurement. As discussed in F5.1.3, this is not the case. As shown in Figure F6, curve 1, the bit sensitivity estimate has a distribution. When this distribution is applied to $S$ of equation (3), the resultant degradation dispersion is greater. An easy way to estimate the dispersion for this measurement is to use a Monte Carlo simulation of the degradation measurement. In the simulation, the sensitivity measurement is first simulated and the result obtained is used in the degradation simulation. In this way, the sensitivity variation is included in the all over simulation. In the simulation as in the measurement, which is a ratio measurement, the degradation estimate is obtained by subtracting the results of the degradation measurement from the estimate of the sensitivity. Since there is a positive correlation (for this example, the correlation coefficient is 0.52 as determined by the Monte Carlo simulation) between the sensitivity estimate and the degradation, this reduces the dispersion. It is interesting to note that for this example curves 3 and 5 are nearly the same. Curve 5 of Figure F6 is a probability histogram of the result of 5 000 simulated measurements, and curve 6 is the cumulative probability. The results of the simulation indicate an accuracy of the degradation measurement of 0.09 dB and a dispersion of $-0.6$ to 1.0 dB.

Since the Monte Carlo simulation is more representative of the method of measurement, for the rest of this appendix the degradation dispersion values stated will be from Monte Carlo simulations. However, the analysis given in F6.1 and F6.2 provides a good insight into the process of the method of measurement.

F6.3 *Character string sensitivity measurement*

The only difference from the bit stream sensitivity analysis (see F5.5.1) for character string sensitivity measurement is that $Err_{char}$ is substituted for $Err_{bit}$ in equations (7) and (8). For this example $Err_{char}$ is given in equation (4) and the results are shown in Figure F7, curves 1 and 2. Since the character error ratio curve (see Figure F2, curve 1) is steeper than the bit error ratio curve, the dispersion will be less. The accuracy of this example is −0.003 dB and the dispersion is about −0.35 to 0.3 dB.

F6.4 *Character string degradation measurement*

The above statement is also true for the character string analysis (see F5.5.2). For this example, the Monte Carlo simulation results are shown in Figure F7, curves 3 and 4. The accuracy for this example is 0.015 dB and the dispersion is about −0.8 to 0.9 dB.

F7. **Model for the up/down method of measurement of selective calling and message sensitivity**

For this dicussion, the message will be as discussed in F5.3. A careful review of Figure F8 will help one to understand the up/down process. This discussion will also be applicable to selective calling, however many selective calling error ratio curves will be steeper than the example used here.

The up/down method differs from the straddle method because the input signal level can be either increased or decreased depending upon the outcome of each transmission. Since the change in signal level is depending upon the preceding steps, the up/down method of measurement can be modelled as a simple Markov chain.

An example of one of the Markov equations is shown below and indicates that the probability of being at level $n+1$ dB is the sum of two probabilities:

1) the probability of being at the $n$ dB level, times the probability of not having three consecutive successes,

2) the probability of being at the $n+2$ dB level, times the probability of three successful decodes.

$$P_{n+1} = P_n[1-(1-Err_n)^3] + P_{n+2}(1-Err_{n+2})^3 \qquad (12)$$

where

$P_n$, $P_{n+1}$ and $P_{n+2}$ are the probabilities of being at the $n$ n+1 and n+2 dB levels

$Err_n$ and $Err_{n+2}$ are error ratios at the $n$ and n+2 dB levels

the $n$, n+1 and n+2 dB levels are the input signal levels in dB for curve 1 of Figure F3

*Notes* 1. — In the up/down method of measurement, the input signal levels are spaced at one dB intervals.

2. — For simplicity, the input signal level to the receiver is used in this discussion, but many of the methods of measurement are written to adjust the input signal level using an attenuutor.

Similar equations can be written for each input signal level.

Another equation which says that the sum of the probabilities of being at each level is one, is:

$$P_{n-6} + P_{n-5} + \ldots + P_{n+6} = 1 \qquad (13)$$

Equation (13) along with equation (12) for each level, less one, makes a set of simultaneous equations which can be solved for the values of $P_n$. Since the values of $P_n$ will be different depending on the starting value, the $P_n$ values for many starting values were calculated and the envelope of the $P_n$ values is shown in Figure F9, curve 1.

### F7.1 *Message and selective calling accuracy*

The first moment of curve 1 will provide a value for the accuracy for the message sensitivity measurement and, for this example, it is 0.02 dB. This indicates that this method of measurement for this example will on the average find the input signal level that will produce an error ratio of 0.2. Similar results will be obtained for error ratio curves that differ considerably from the example used here.

### F7.2 *Message and selective calling dispersion*

It is somewhat more involved to determine the dispersion for the up/down methods as it is estimated using the statistics of sampling.

The standard deviation, $\sigma$, of curve 1 of Figure F9 is 0.94 dB The probability distribution of the result of the measurement is estimated using the sampling theory. Let each level recorded in the measurement be a sample (there are ten samples in Figure F9) taken from the distribution of curve 1. For any one measurement, the samples will always be in intervals of one dB, but if many measurements starting at many different levels are used, the use of the continuous curve is valid. The result of the method of measurement is the average of these samples. The distribution of the results of the measurement (the averages) will have a normal probability distribution [2] with a mean equal to the mean of the distribution whose standard deviation is the accuracy. The standard deviation of the results of the measurement, $s$, will be as follows:

$$s = \sigma / \sqrt{x} \tag{14}$$

where

$x$ is the number of samples per measurement

$\sigma$ is the standard deviation of each sample

While the average number of transmissions per level change recorded, $N$, can vary from 2 to 3 depending on the slope of the error ratio curve, the value of $N$ for this example is about 2.36. For very steep error ratio curves, $N$ approaches the value of 2. $N$ is obtained using the following relationship:

$$N = \sum_{n=-6}^{n=6} P_n \left[ 3 ( 1 - Err_n )^3 + 3 ( 1 - Err_n )^2 Err_n + 2( 1 - Err_n ) \, Err_n + Err_n \right] \tag{15}$$

where

$P_n$ is the probability of being at level $n$ ( see clause 7 )

$Err_n$ is the error ratio at level $n$

From the above, $x$ is the number of transmissions, $T$, in the measurement divided by $N$. For the sensitivity measurement $T = 20$ and $N = 2.35$.

The value of the dispersion for this example is:

$$\text{dispersion} = \text{accuracy} \pm 1.645 \, \sigma / \sqrt{T/N} = -0.024 \pm 0.532 \text{ dB} \tag{16}$$

The cumulative distribution of a normal distribution curve for a mean of 0.024 dB and a dispersion of ± 0.53 dB is shown in curve 2 of Figure F9.

For the up/down method of measurement, the dispersion can be made smaller by increasing the number of transmissions of the message used.

### F7.3 *Message and selective calling degradation measurements*

The analysis of the up/down method of measurement used for degradation measurements is similar to that for sensitivity except that, since it is the unwanted signal that is varied, the direction to change the input signal based on the outcome of the transmission is reversed ( see F5.1.2 ).

Using, for this example, the error ratio curve 3 of Figure F3 and a Monte Carlo simulation, curve 3 of Figure F9 is generated. From this the accuracy of this example is calculated to be about 0.087 dB.

The cumulative distribution of the message degradation is shown in curve 4 of Figure F9 and shows a dispersion for this example of −1.9 to 1.7 dB. This is just within the goal given in F3.2.

### F7.4 *Model for fading measurement*

### F7.4.1 *Bit stream and character string fading measurements*

Since these measurements use the straddle method, the analysis of the example of the bit stream and character string is similar to the discussion in F6.1 and F6.3 except for using the error ratio curve 1 from Figure F4; the results are shown in Figure F10. Since the bit stream and character string error ratio curves are so similar, the accuracy and dispersion for these measurements are nearly the same. The accuracy is −0.21 dB and the dispersion is about −1.5 to 0.6 dB.

### F7.4.2 *Message and selective calling fading measurements*

This measurement uses the up/down method as discussed in F6 and F6.1, F6.2 and F6.3. The faded message error ratio curve shown in Figure F4, curve 3 is used and the results are shown in Figure F11. For this example, the accuracy is about −0.09 dB and the dispersion is about −0.8 to 0.8 dB.

## F8. **Compliance test**

### F8.1 *Principle of shared risk*

In any compliance test there is a chance that the compliance test will give a wrong decision. Because of this, the compliance tests designed by those who will receive or certify the equipment are designed so there is a high probability of failing the compliance test if the equipment is a little worse than the specification limit. On the other hand, the manufacturer would like to see the compliance tests designed so that there is a high probability of passing the compliance test if the equipment is a little better than the specification limit.

To attempt to meet both requirements, the compliance test in this standard are designed so that, if a receiver-decoder has a radio-frequency parameter that exactly matches the parameter specification, there will be a 0.5 probability that it will pass or fail the compliance test. This is the principle of shared risk. In this circumstance, the error ratio will be the reference error ratio at the specified input signal level.

### F8.2 *Design objectives*

The design goal for sensitivity compliance tests is to meet the principle of shared risk and to have a 0.95 probability of passing the compliance test if the equipment is one dB, or less, better than the specification limit, and to have a 0.95 probability of failing the compliance test if the equipment is one dB, or less, worse than the specification.

For degradation and fading compliance tests, the 0.95 probability of passing or failing are for equipments that are 2 dB, or less, better or worse than the specification.

### F8.3 *Compliance test model*

For the compliance tests used in this standard, the probability of passing the compliance test is a function of the receiver-decoder error ratio at the specified input signal level and is:

$$P\text{passing} = \sum_{K=0}^{K=f} \frac{t\,!\,(\,1\ -\ Err\,)^{(t-k)}\ Err^{k}}{K\,!\,(\,t\ -\ K\,)\,!} \qquad (17)$$

where

| | |
|---|---|
| $P_{\text{passing}}$ | is the probability of passing the compliance test |
| *Err* | is the error ratio when the specified signal level is applied to the receiver-decoder |
| *t* | is the number of transmissions in the compliance tests ( e.g. 18, 33, 78, or 2 556 ) |
| *f* | is the number of failures allowed in the compliance test ( e.g. 3, 6, 15, or 25 ) |

### F8.4 *Risk curve*

#### F8.4.1 *Risk curve for sensitivity measurements*

In equation ( 17 ), *Err* is a function of the input signal level. For the sensitivity measurement, if the receiver-decoder sensitivity is better ( e.g. +2 dB ) than the specified sensitivity, then when the specified signal level is applied to the receiver-decoder, *Err* will be smaller and the receiver-decoder will have a higher probability of passing. The opposite is true if the sensitivity is worse than the specified sensitivity. For this discussion, zero dB is the specified input signal level.

In the examples used in this appendix, *Err* can be determined as a function of the input signal level from the appropriate equations (1) through (11), thus $P_{\text{passing}}$ is a function of the input signal level.

When the function in equation (17) is plotted with *t* and *f* fixed, and the input signal level is varied in accordance with the error ratio function of the equipment being tested, the resultant curve is called a risk curve. Note that the input signal level is given as the ratio of the receiver-decoder parameter ( e.g. sensitivity ) to the specified value of the parameter. The solid-line curve of Figure F12 is derived from equation (1) for the sensitivity bit stream compliance test and is the risk curve. The long-dash curve is for character string and the short-dash curve is for selective calling and message.

#### F8.4.2 *Risk curve for bit stream degradation compliance tests*

This example is derived from the model given in F5.1.2. The result of a degradation measurement is the ratio of the level of the sensitivity, to the unwanted signal level. Therefore, if the sensitivity value used is in error, it will affect the shape of the risk curve. If the sensitivity is low, the risk curve will be shifted to the left, and, if it is high, the curve will be shifted to the right. Curve 1 of Figure F13 was calculated on the basis that the sensitivity was low by −0.5 dB. Curve 2 was calculated using a sensitivity that was high by 0.4 dB ( see Figure F6, curve 2 ). Since for the example used in this appendix the estimate of the sensitivity will fall between these points 90% of the time, it follows that the risk curve will fall between curves 1 and 2 of Figure F13. Curve 3 is the risk curve if the true sensitivity were used. The dispersion for the compliance test of degradation is the limits of the input signal levels between the 95% point of curve 1 and the 5% point of curve 2, or −2.2 to 1.6 dB.

#### F8.4.3 *Risk curve for character string degradation compliance tests*

Figure F14 shows the results of risk curves based on the sensitivity values of −0.4 and 0.3 dB ( see Figure F7, curve 2 ); the dispersion is −1.5 to 1.2 dB.

#### F8.4.4 *Risk curve for message and selective calling degradation compliance tests*

Figure F15 shows the results of risk cvrves based on the sensitivity values of −0.55 and 0·5 dB ( see Figure F9, curve 2 ); the dispersion is −2.7 to 1.9 dB.

F8.4.5 *Risk curve for fading compliance tests*

Figure F16 shows the risk curve for these examples for fading. The bit stream and character string are almost identical and are shown by the solid-line curve. The selective calling and message curve is the short dash-curve.

## F9. References

[1] M. Schwartz et al. "Communication Systems and Techniques". McGraw-Hill Book Company, New York, 1966.

[2] American Statistical Association, page 109, Volume 43, by W. J. Dixon and A. M. Mood.

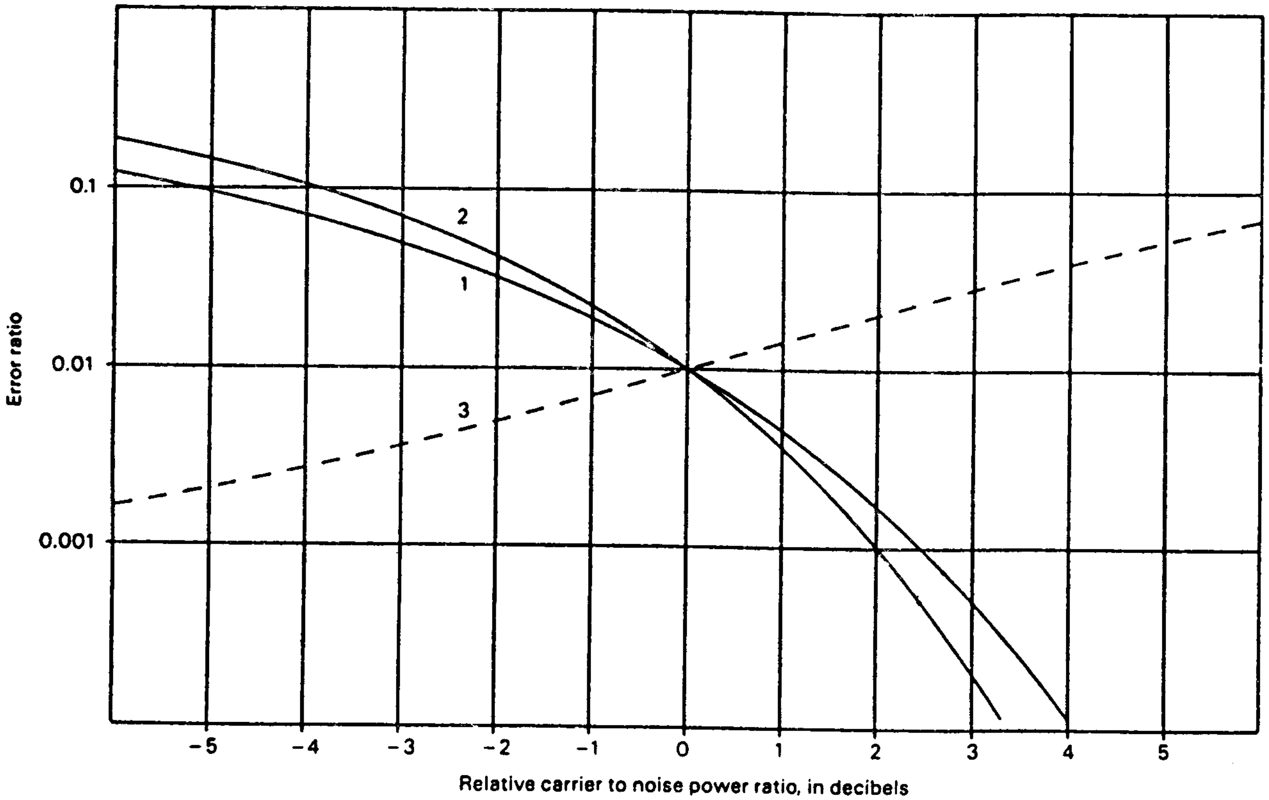


Figure F1 - Bit error ratio versus input signal level

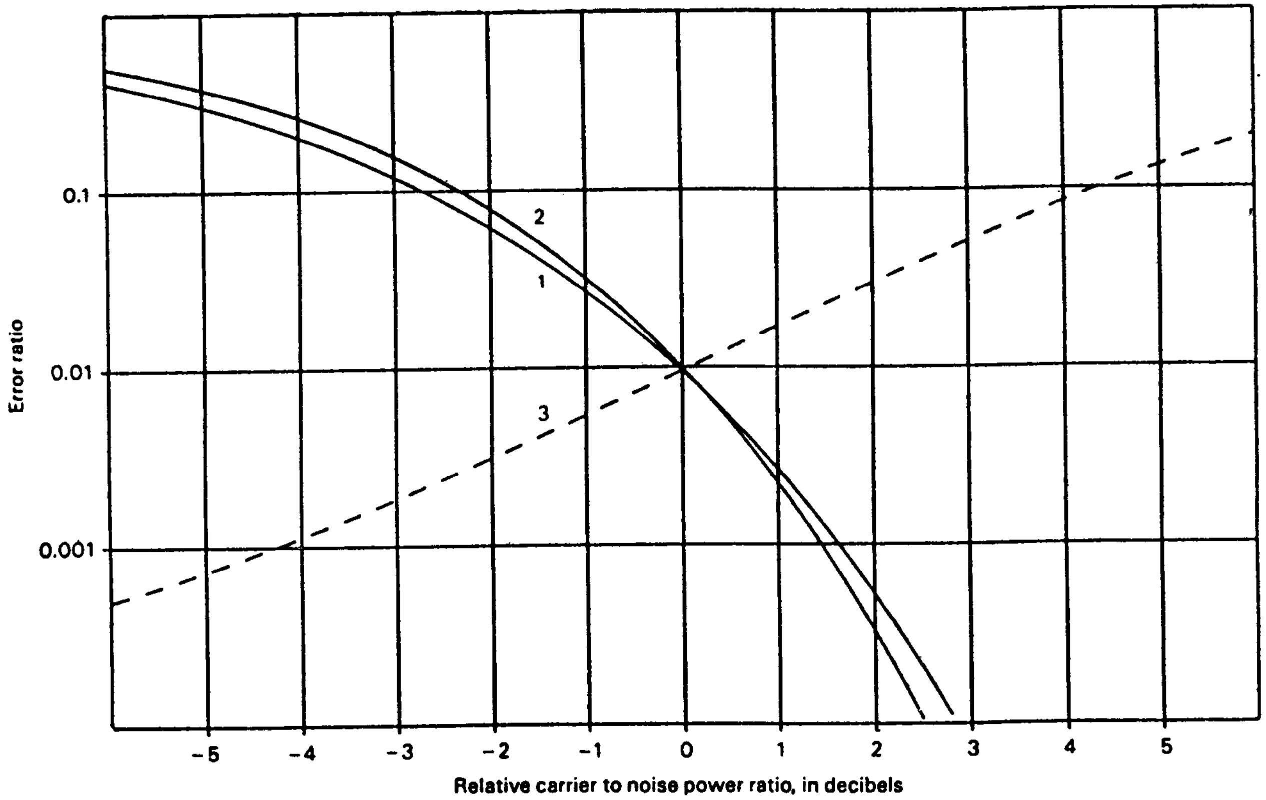


Figure F2 - Character error ratio versus input signal level

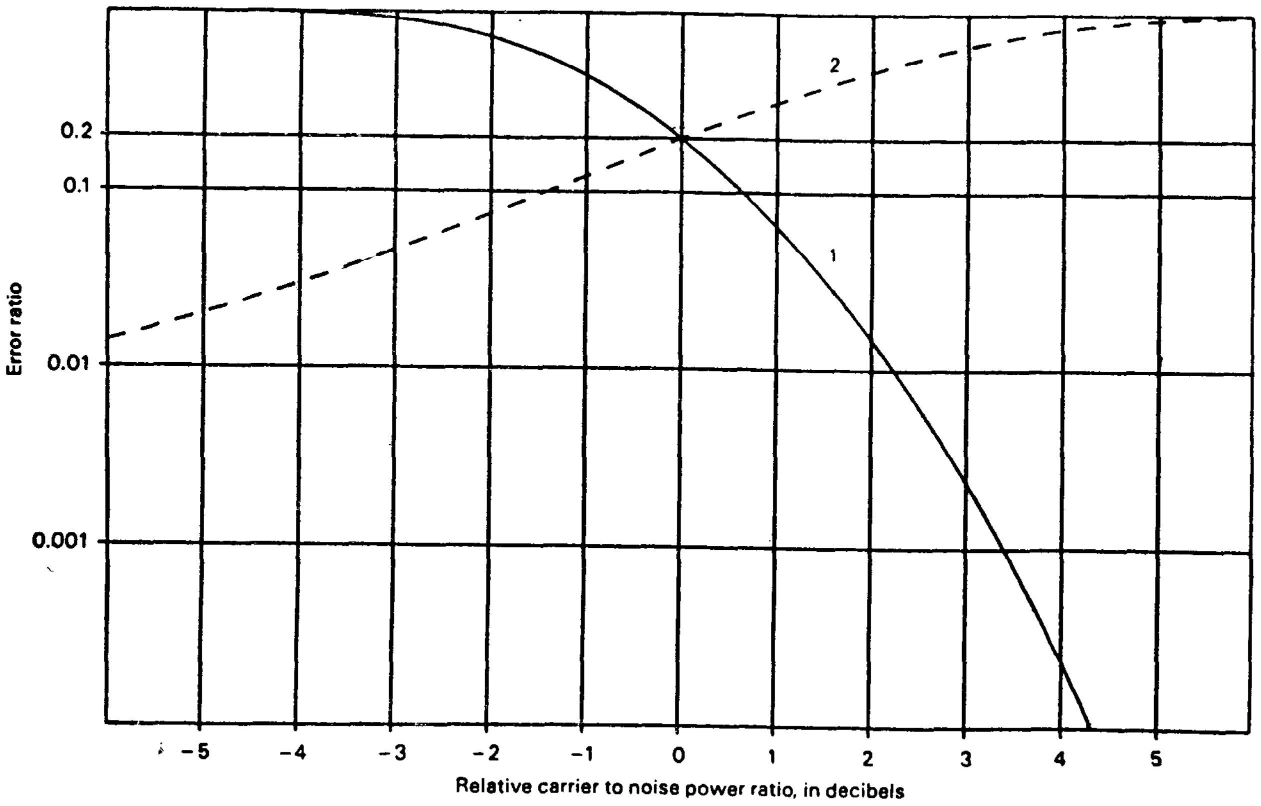


Figure F3 - Message error ratio versus input signal level

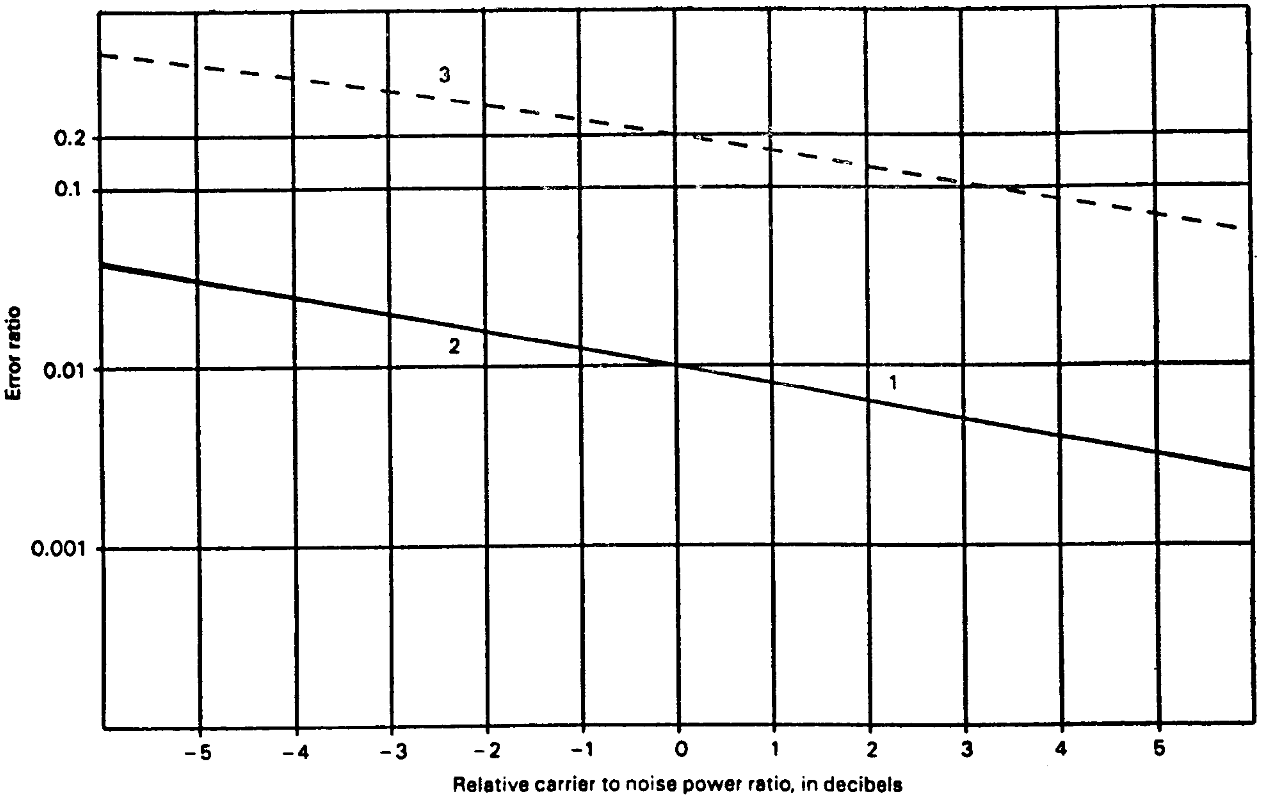


Figure F4 - Bit, character and message error ratio versus faded input signal level

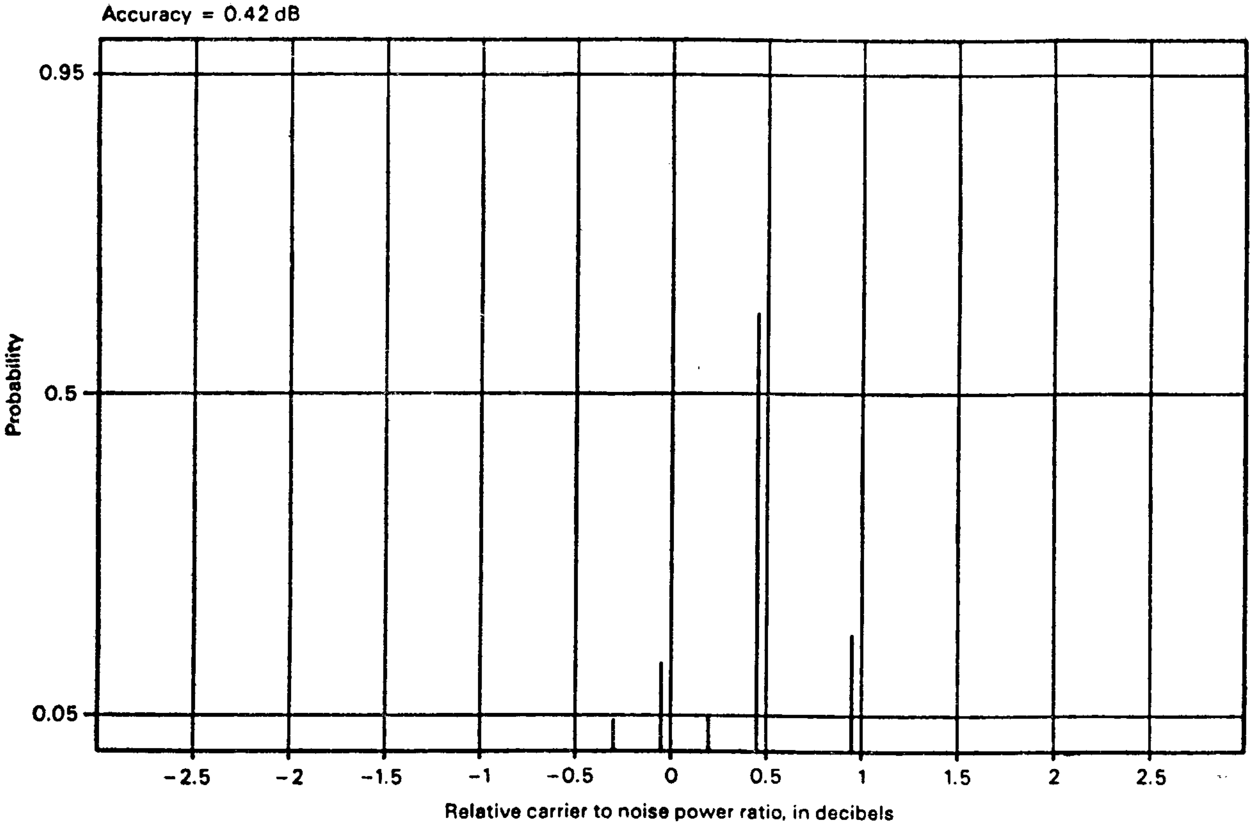


Figure F5 - Straddle method - Sensitivity (Bit stream) - Accuracy and dispersion

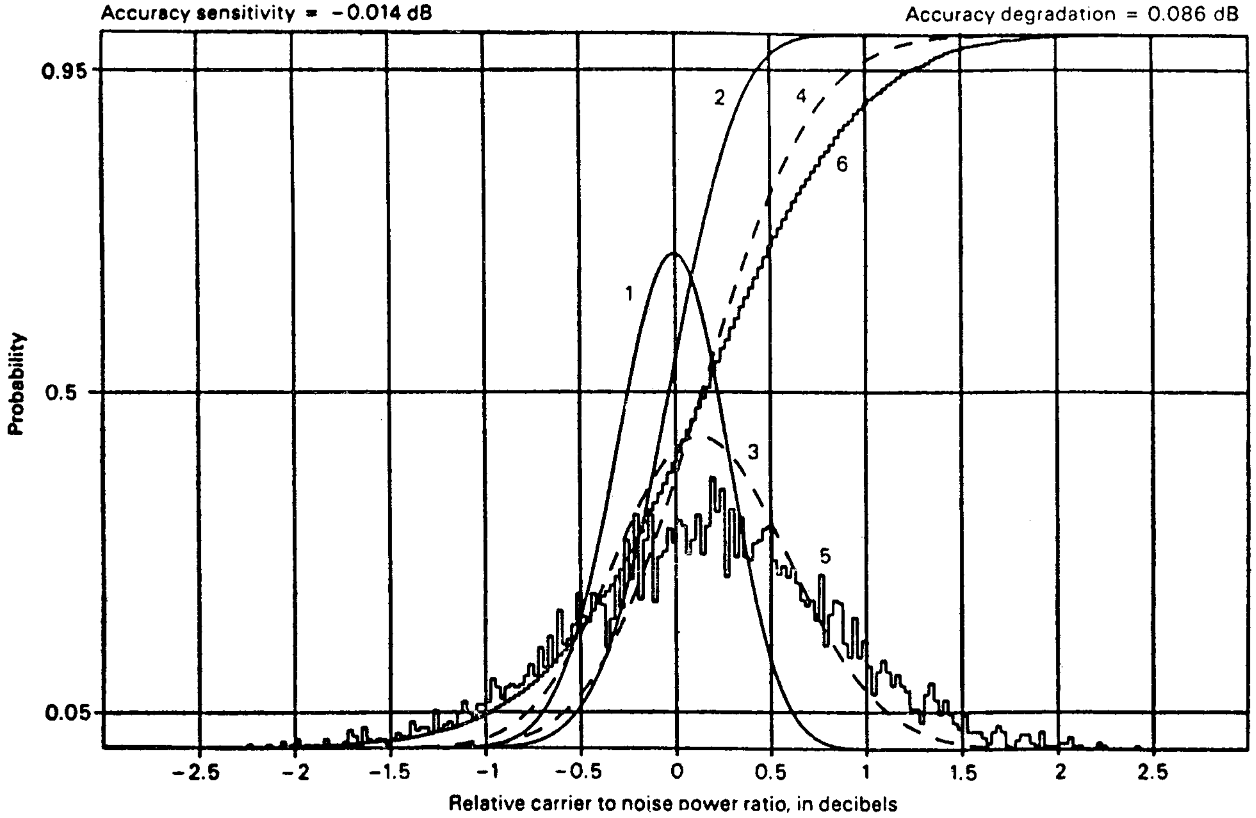


Figure F6 - Straddle method - Bit stream - Accuracy and dispersion

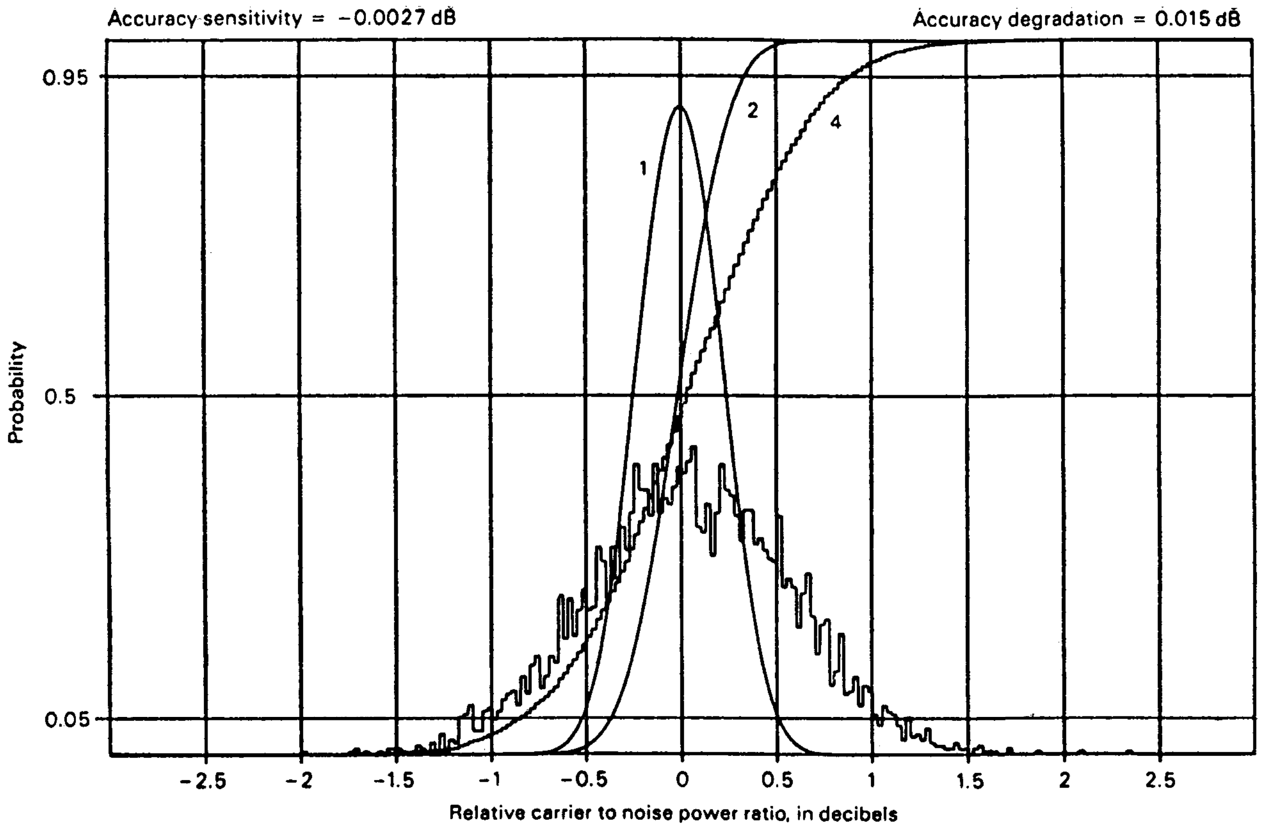


Figure F7 - Straddle method - Character string - Accuracy and dispersion

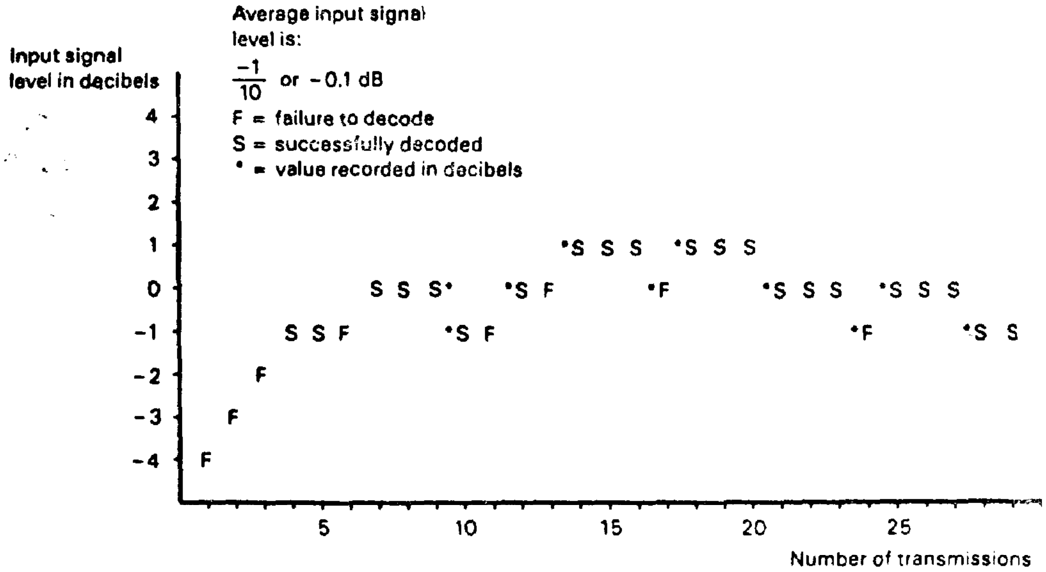


Figure F8 - Example of the up/down method of measurement of sensitivity

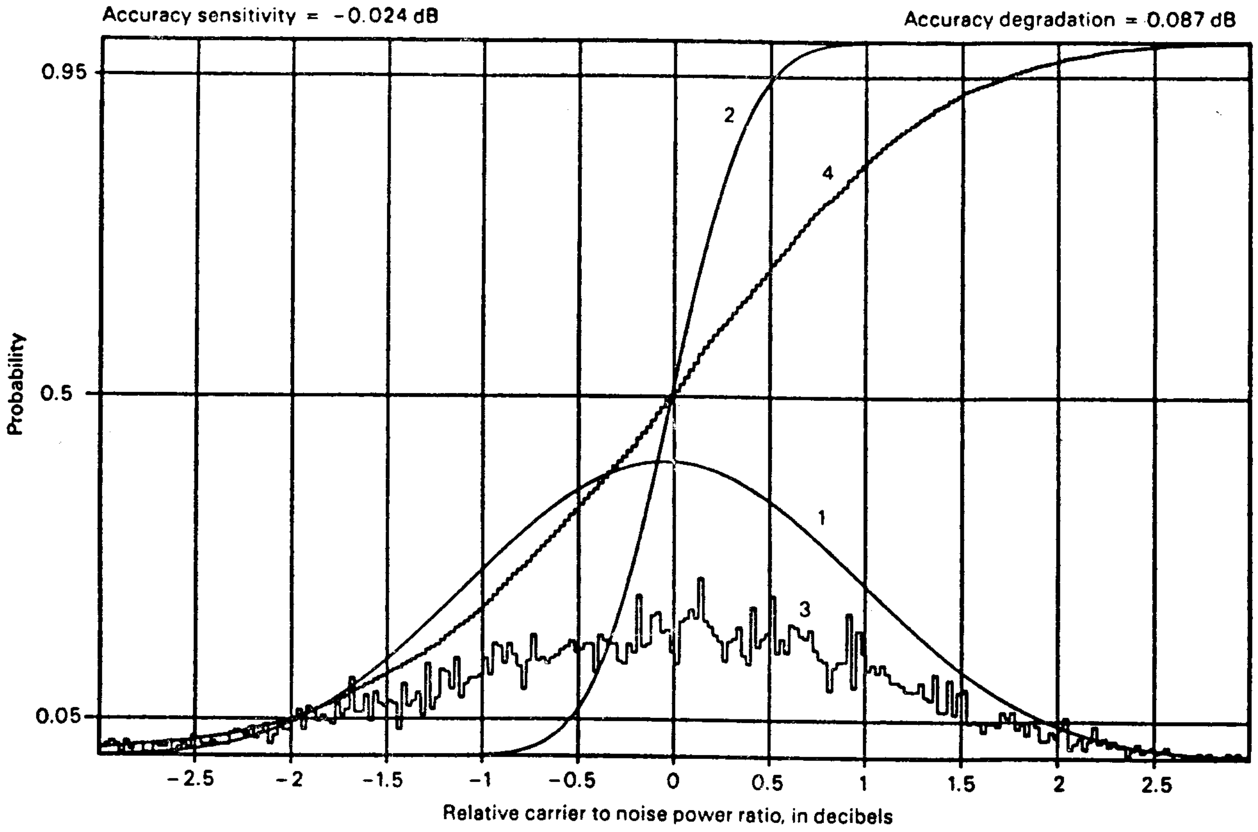


Figure F9 - Up/down method - Message - Accuracy and dispersion

Accuracy sensitivity (fading) = −0.21 dB

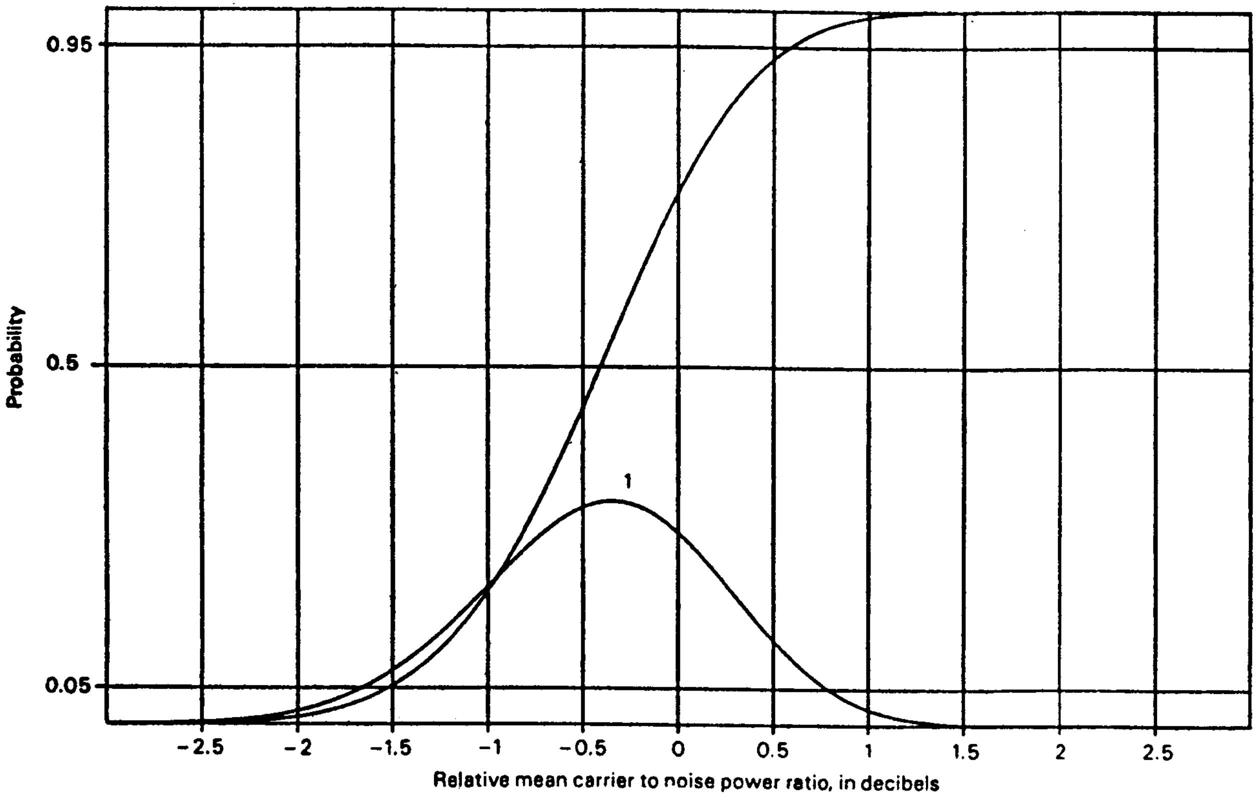


Figure F10 - Straddle method fading - Bit stream and character string - Accuracy and dispersion

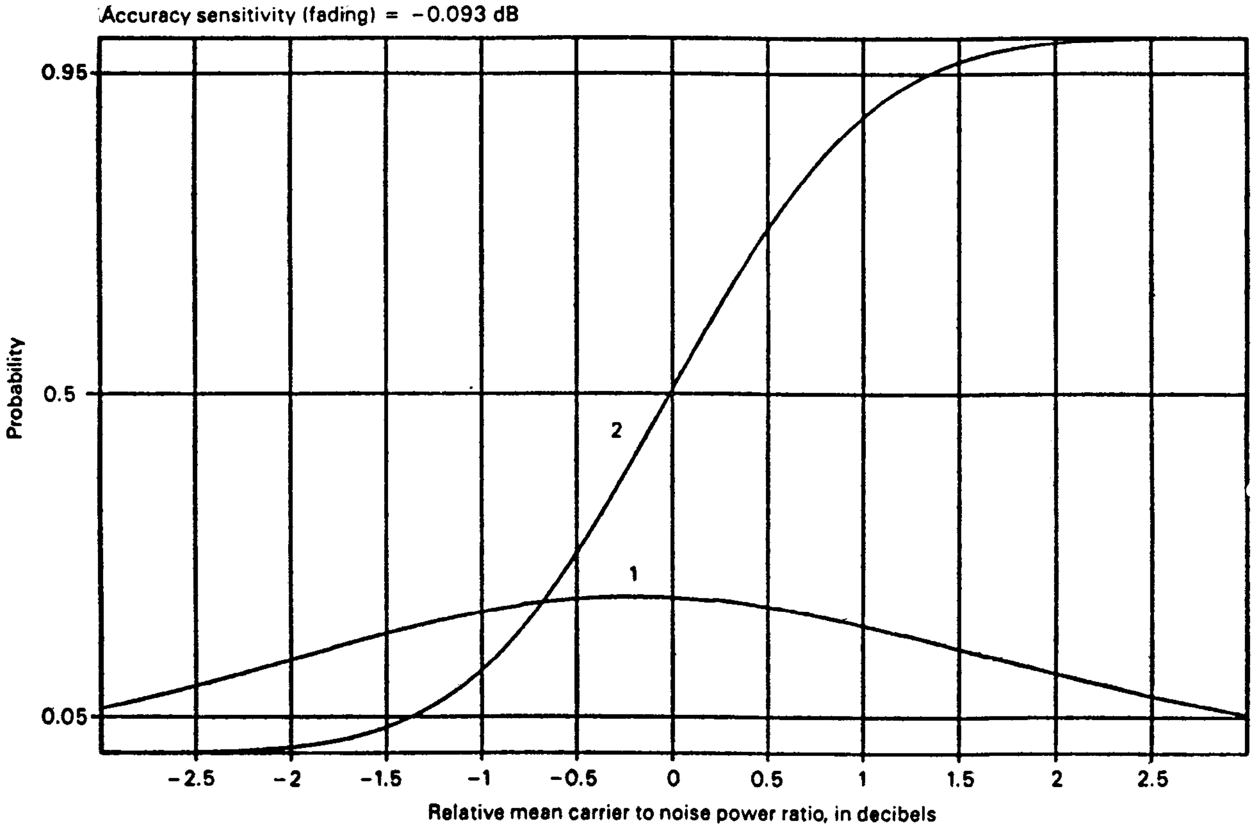


Figure F11 - Up/down method fading - Message - Accuracy and dispersion

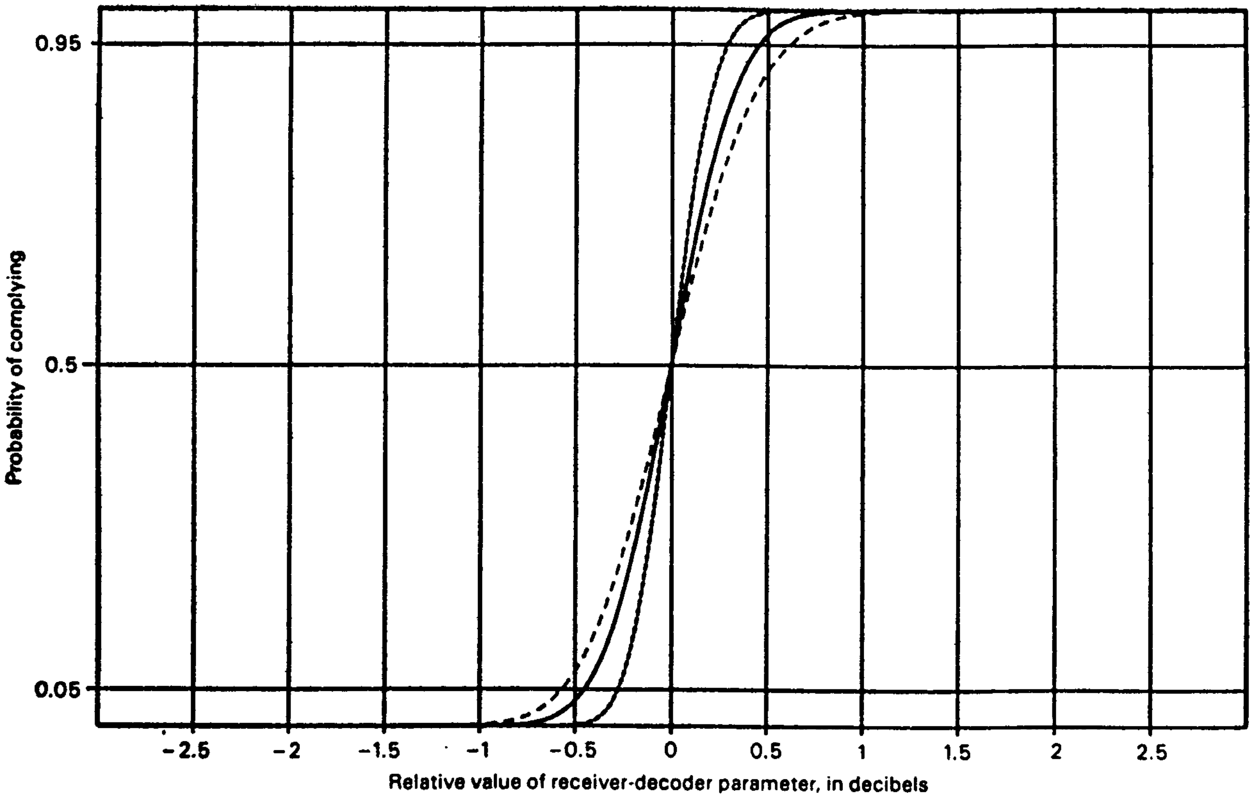


Figure F12 - Risk curve for sensitivity - Bit stream, character string and message

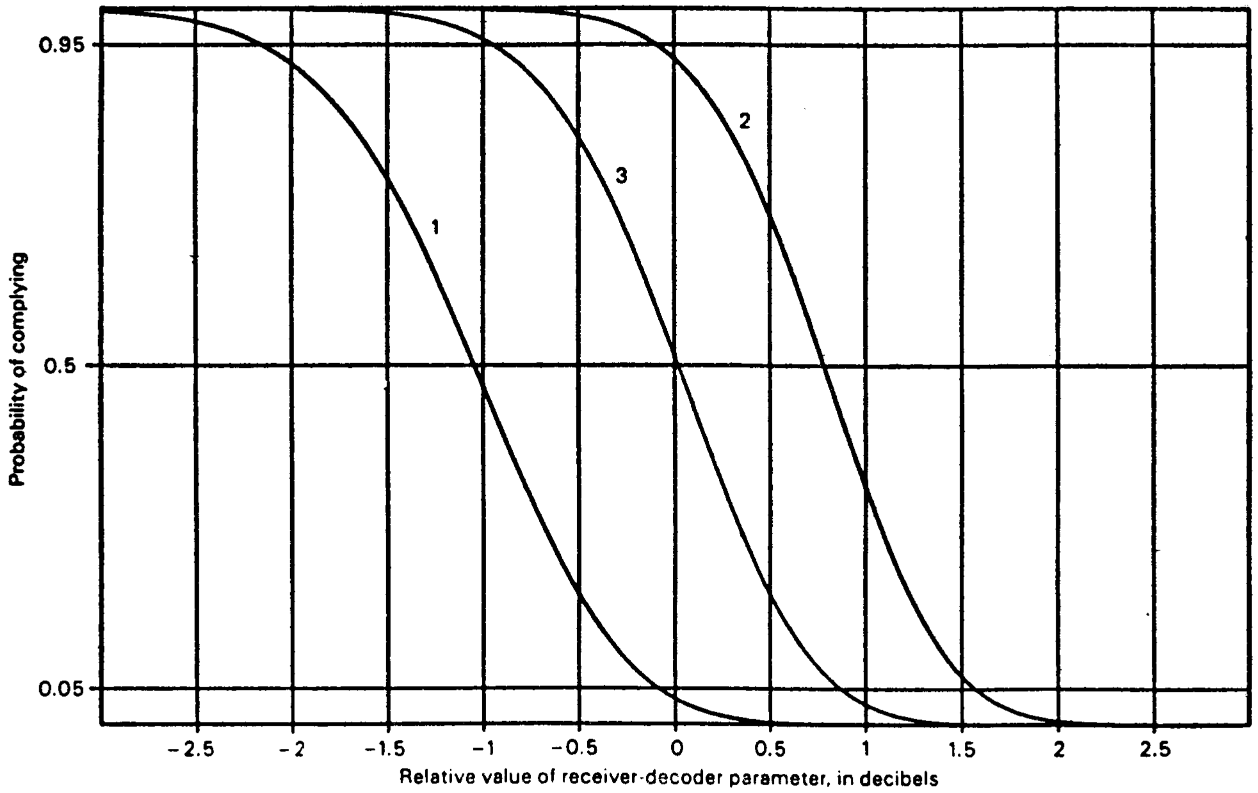


Figure F13 - Risk curve for degradation - Bit stream

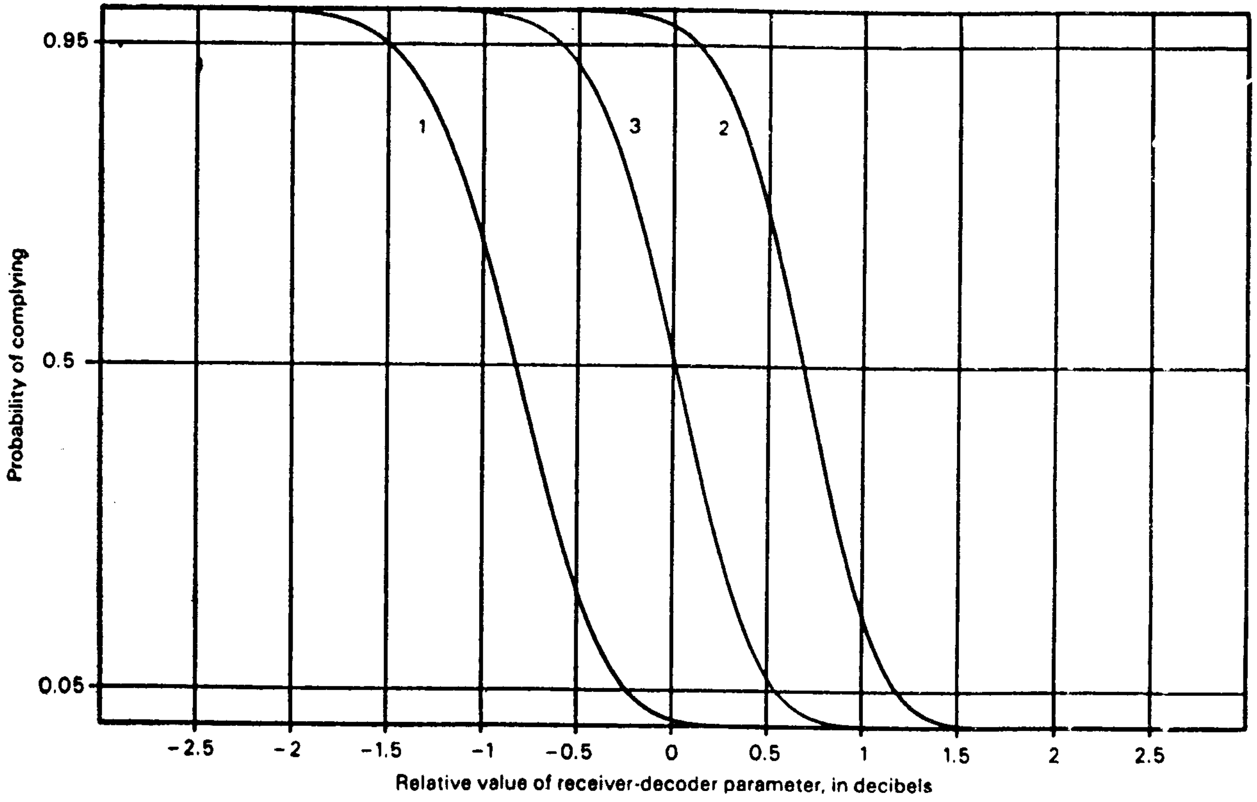


Figure F14 - Risk curve for degradation - Character string

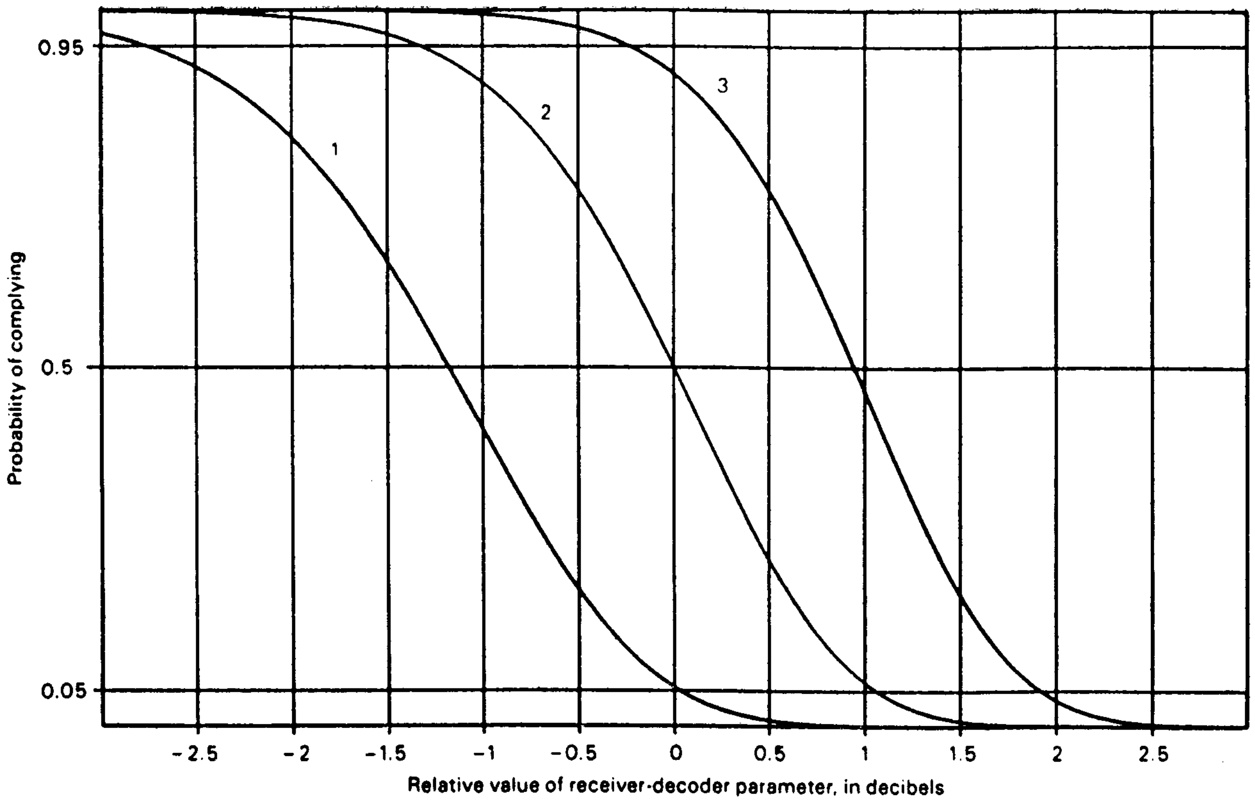


Figure F15 - Risk curve for degradation - Message

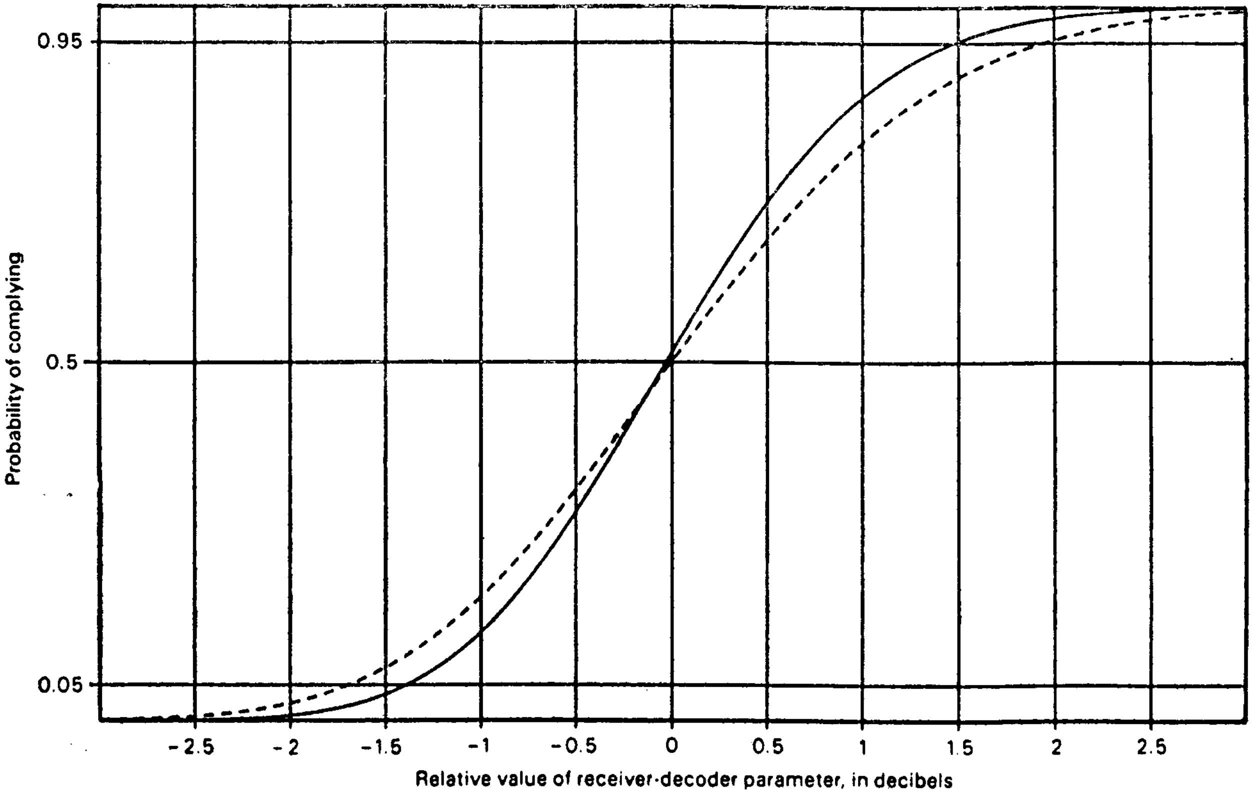


Figure F16 - Risk curve for fading - Bit stream, character string and message

# APPENDIX G

## MEAN TIME BETWEEN FALSE CALLING RESPONSES($M$) (SELECTIVE CALLING)

This standard assumes that time between false calling responses has an exponential distribution, and the estimate for $M$ is given by the following formula:

$$M = \frac{\text{time for } n \text{ false calling responses to occur}}{n} \text{ in hours}$$

where $n$ is the number of false calling responses.

Eight false calling responses have been selected for the noise falsing measurement in order to keep the span for this measurement within a usable value.

The cumulative probability distribution of the estimates of $M$ that will be obtained when many measurements are made on the same equipment, as compared with the true value of $M$ or the equipment, can be described by the chi-squared distribution where $2n$ is the number of degrees of freedom. From the chi-squared table for 16 degrees of freedom, it is determined that 95% of the estimates for $M$ obtained by this measurement will be 0.5 or more times the true value of $M$ and also that 95% of the estimates for $M$ will be 1.64 or less times the true value of $M$. Therefore, 90% of the estimates for $M$ will be between 0.5 and 1.64 times the true value of $M$, and this is the span of this measurement.

Since the estimate of $M$ has the chi-squared distribution, the total time to make the measurement also has this type of distribution. Therefore, 90% of the measurements will require a total time of between 3.98 and 13.15 times the value of $M$ of the equipment being measured.

The measurement should not be specified if it is impractical to measure the equipment for this length of time. If it can be assumed that various different items of equipment have the same value of $M$, this measurement can be made using all these items of equipment simultaneously. The measurement is made until a total of eight false calling responses has occurred, and the time is the sum of the times of each of the different equipment.

*Probability of falsing*

The probability of a given number of false calling responses occurring in a specified period of time can be calculated using the following formula:

$$P(t) = \frac{(t/M)^n}{n!} e^{-(t/M)}$$

where

$t$ is the specified period of time

$n$ is the given number of false calling responses

The value of $M$ used will be the estimate of $M$ obtained from the measurement. The magnitude of the span of the value of $M$ has been discussed. When the estimate of $M$ is used to estimate the probability of a given number of false calling responses occurring in a specified period, the effect of the span of $M$ should be considered. The effect can be very large when the probability is small.

*Discussion of the compliance tests*

In any compliance test there is a risk that the test will give a wrong decision. The compliance test designed by those who will receive or certify equipment will be such that, if the equipment performance is a little worse than the specified limit, there will be a high probability of failure. On the other hand, the manufacturer would like to see the test designed so that there is a high probability of passing the test if the euiqpment is a little better than the specification limits.

In an attempt to meet both requirements, the compliance tests in this standard are designed so that if a receiver-decoder has a mean time between false calling responses that exactly matches the specification, there will be a 50% probability that it will pass and a 50% probability that it will fail the compliance test. This is the principle of shared risk.

The design goal for these tests is to have a 95% probability of the equipment failing the test if it has an $M$ that is one half of the specified value, and a 95% probability of passing the test if it has an $M$ of twice the specified value.

For the type of compliance test used in this standard, the probability of a receiver-decoder passing the test is a function of the ratio $R$, the actual receiver-decoder $M$ to the spcified value, and is given by:

$$P_{(\text{passing})} = \sum_{i=0}^{i=8} (8.67/R)^i \exp(-8.67/R)/i!$$

where

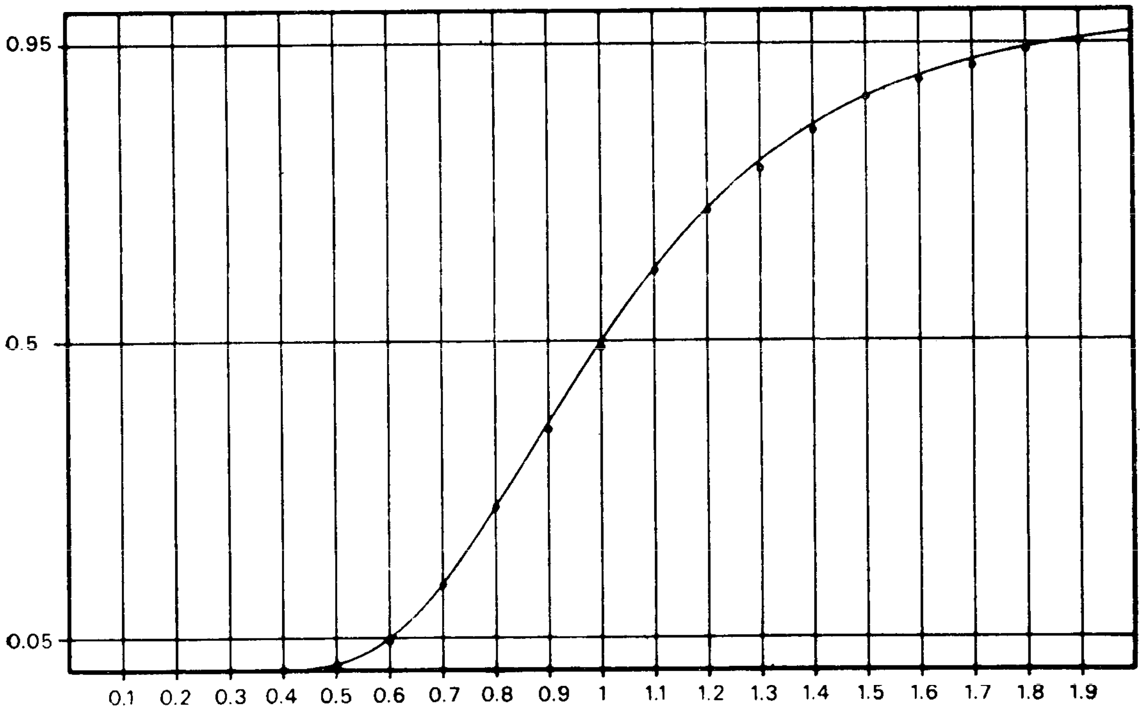
$P_{(\text{passing})}$ is the probabilty of passing the compliance test
$R$ is the ratio of the equipment $M$ to the specified value

When the above equation is plotted it is called a risk curve and it is shown in Figure Gl.

When $R$ is either small or large, some time can be saved by truncating the test using the following rules. Where $T$ is the total time that the test has run measured in the same units as $M$, and $F$ is the number of false calling responses observed during the time $T$:

— stop the test and pass the equipment if $T$ is greater than $3 + F$,
— stop the test and fail the equipment if $F$ is greater than $3 + T$.

The modified risk curve is shown by the points in Figure Gl. The data points were obtained by simulation.



**R**, the ratio of the receiver-decoder false calling response to the specified false calling response.

FIG. Gl. — Risk curve — False responses due to noise (selective calling).

# APPENDIX H

## ALTERNATIVE TEST MOUNTING ARRANGEMENTS FOR EQUIPMENT WHICH IS HAND-HELD OR CARRIED ON THE PERSON WHILE IN NORMAL OPERATION

### H1. Simulated-man test device

Most radio-paging receivers have an intergral antenna. In normal operation, the radio pager is worn on the person and most often is clipped to the clothing at the person's waist. Radio-paging antennas are designed for optimum performance when worn on the person. Therefore, to standardize the radio-paging radiation sensitivity measurements, a test device is used to simulate the human body. This test device consists of a standard container filled with salt water, and is referred to in this appendix as the simulated man.

The simulated man is used to measure the reference radiation sensitivity (selective calling) and/or average radiation sensitivity (selective calling) of radio pagers.

H1.1 *Description*

| | |
|---|---|
| Material: | Cast acrylic tube closed at both ends |
| Height: | 1.7 ± 0.1 m |
| Outside diameter: | 305 ± 2 mm |
| Sidewall thickness: | 4.8 ± 0.2 mm |
| Top and bottom thickness: | 30 ± 2 mm |

Filled with salt (NaCl) solution of 1.49 g per litre of distilled water ($H_2O$).

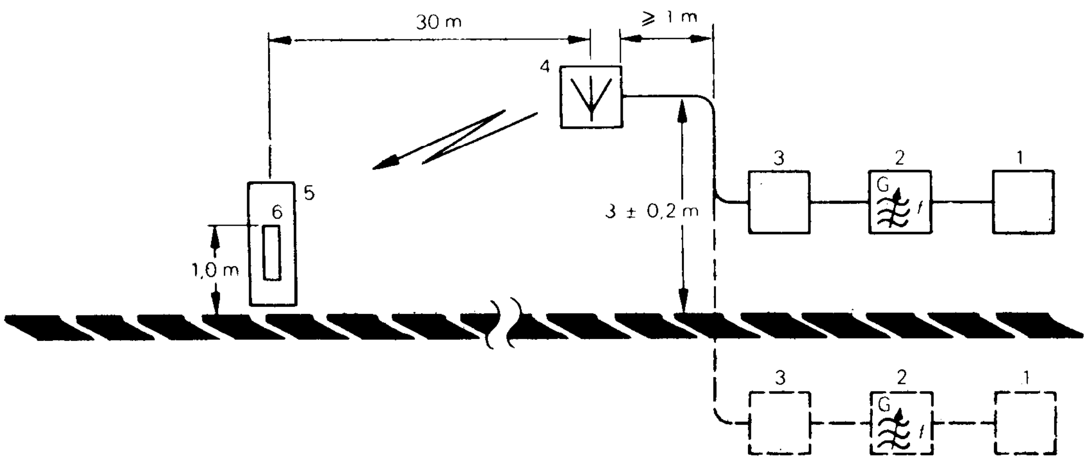
The simulatted man shall rest on the surface of the radiation test site.

H1.2 *Location of radio pager for measurement*

The top of the radio pager should be 1.0 ± 0.1 m from the ground. The radio pager should be fixed on the surface of the simulated man without a gap between them.

### H2. Simulated hand

Under consideration.



**1** = encoder
2 = radio-frequency generator
3 = 80 dB step attenuator, steps of 1 dB
4 = transmitting antenna
**5** = simulated man
6 = receiver under test

Care should be taken to ensure that the field in the vicinity of the receiver under test is not disturbed by the test equipment

FIG. H1. — Measuring arrangement for radio pagers on a radiation test site (30m).

# APPENDIX J

## GUIDE FOR THE CONSTRUCTION AND MEASUREMENT OF A RADIO-FREQUENCY COUPLING DEVICE (RFCD)

The equipment parameter measurements applicable to this radio-frequency coupling device (RFCD) are all ratio measurements pertaining to receiver radio-frequency energy, for example, receiver selectivity, spurious response immunity and intermodulation immunity.

RFCDs for higher frequency ranges are under consideration.

### J1. RFCD characteristics

| | *Limits* | |
|---|---|---|
| Useful frequency range: | 1 MHz to 200 MHz for Size I<br>1 MHz to 100 MHz for Size II | |
| Available field strength in the RFCD: | See Clause J5 | |
| | *Size I* | *Size II* |
| Equipment size limits (antenna included): | Length = 200 mm | 400 mm |
| | Width = 200 mm | 400 mm |
| | Height = 250 mm | 500 mm |

### J2. RFCD construction

The RFCD is a transmission line of stripline class.

The RFCD is made of three pieces of highly conductive metal (e.g. copper sheet) that are sufficiently rigid (e.g. strengthened by wood) to support the equipment under test mounted in the stripline.

The shape and size of the RFCD is shown in Figure J1. It is open on both sides. The RFCD has an impedance of 100 Ω and shall be terminated with this impedance by a resistance having less than 5 Ω of reactance at any frequency from 1 MHz to 200 MHz. Both outer conductors are connected by the sheilding of the transmission line.

The RFCD shall be matched to the transmission line impedance with matching networks (see Figures J2 and J3) with resistors that have less than 5% reactance at any frequency from 1 MHz to 200 MHz (e.g. for a 50 Ω transmission line, a shunt and series resistance of 70.7 Ω should be used).

Care should be taken to choose resistors with very low inductance and capacitance (e.g., surface mounting resistors) because the size and the material of the resistors have a great influence on the reactance at frequencies especially above 100 MHz.

### J3. Measurement of the RFCD

After constructing the RFCD, it is necessary to measure the radio-frequency behaviour of the RFCD in the frequency range from 1 MHz to 200 MHz to determine at what frequency and by how much the field strength deviates from a constant value.

#### J3.1 *Method of measurement*

A 40 mm monopole antenna, which is short in comparison to a quarter wave length for the highest measuring frequency, is mounted on the lower outer conductor, pointing to the inside of the stripline. The antenna base shall be located in the centre of the area designated to locate the receiver under test. This monopole is connected as the antenna base to a 50 Ω, 20 dB pad, and from there with a low loss cable to the selective measuring device.

Connect a radio-frequency signal generator followed by an amplifier if necessary and apply 1 V to the input of the RFCD.

The 40 mm monopole antenna has an impedance which is, for practical purposes, capacitive and which gives a voltage, in a constant field strength, that will increase by 6 dB for each time the frequency is increased by a factor of 2.

Vary the frequency from 1 MHz to 200 MHz in steps not greater than 3% and record the frequency and the reading of the selective measuring device.

### J3.2 *Presentation of results*

*Note.* — See Figure J4 for an example graph.

*a)* Convert the selective measuring device readings recorded in Sub-clause J3.1 to dB ($\mu$V).

*b)* Plot on a graph the frequency values recorded in Sub-clause J3.1 on a log scale and the dB ($\mu$V) values converted in Step *a)* on a linear scale.

*c)* Fit a straight line, with increases of 6 dB for each time the frequency is increased by a factor of 2, to the points plotted on the graph.

*d)* At any frequency, the difference between the straight line and the plotted value is the deviation. This is used to correct the spurious response measurement. The deviation is subtracted from the measurement.

### J4. Position of the equipment under test

The equipment under test shall be mounted on a pedestal made of a low dielectric material (dielectric constant of less than 2) which places it at least 10 mm above the lower conductor.

The equipment shall be centred in the horizontal plane of the RFCD in the following position:

*a)* For equipment having an integral antenna, mount the equipment so that the antenna is in a vertical position, with the vertical axis that is closest to vertical in normal use.

*b)* For equipment having a rigid external integral antenna, mount the equipment so that the antenna is in a vertical position.

*c)* For equipment with a non-rigid external integral antenna, mount the antenna vertically with a non-conducting support.

*d)* Or as agreed with the manufacturer.

### J5. Explanation of the the term 'available field strength in a radiation stripline'

*Note.* — In this standard the measurements that use the RFCD are of the ratio type and are made in terms of the ratio of the voltages applied to the input of the RFCD. Therefore, knowledge of the absolute value of the field strength in the RFCD is not required.

The following information is provided for those who wish to know the values of the field strengths involved in the measurements.

The available field strength is equal to the voltage on the central conductor divided by the distance from the central conductor to the outer conductor in metres. The relationship of the field strength in the RFCD to the input voltage is given by the following formula:

$$\text{field strength} = V_1 \times C \times A \times \frac{1}{H} \ \mu\text{V/m}$$

where

$V_1$ is the voltage in μV at the input to the RFCD

$A$ is the voltage ratio of the voltage on the central conductor to $V_1$ and in this RFCD is equal to 100/170.7 or 0.5858

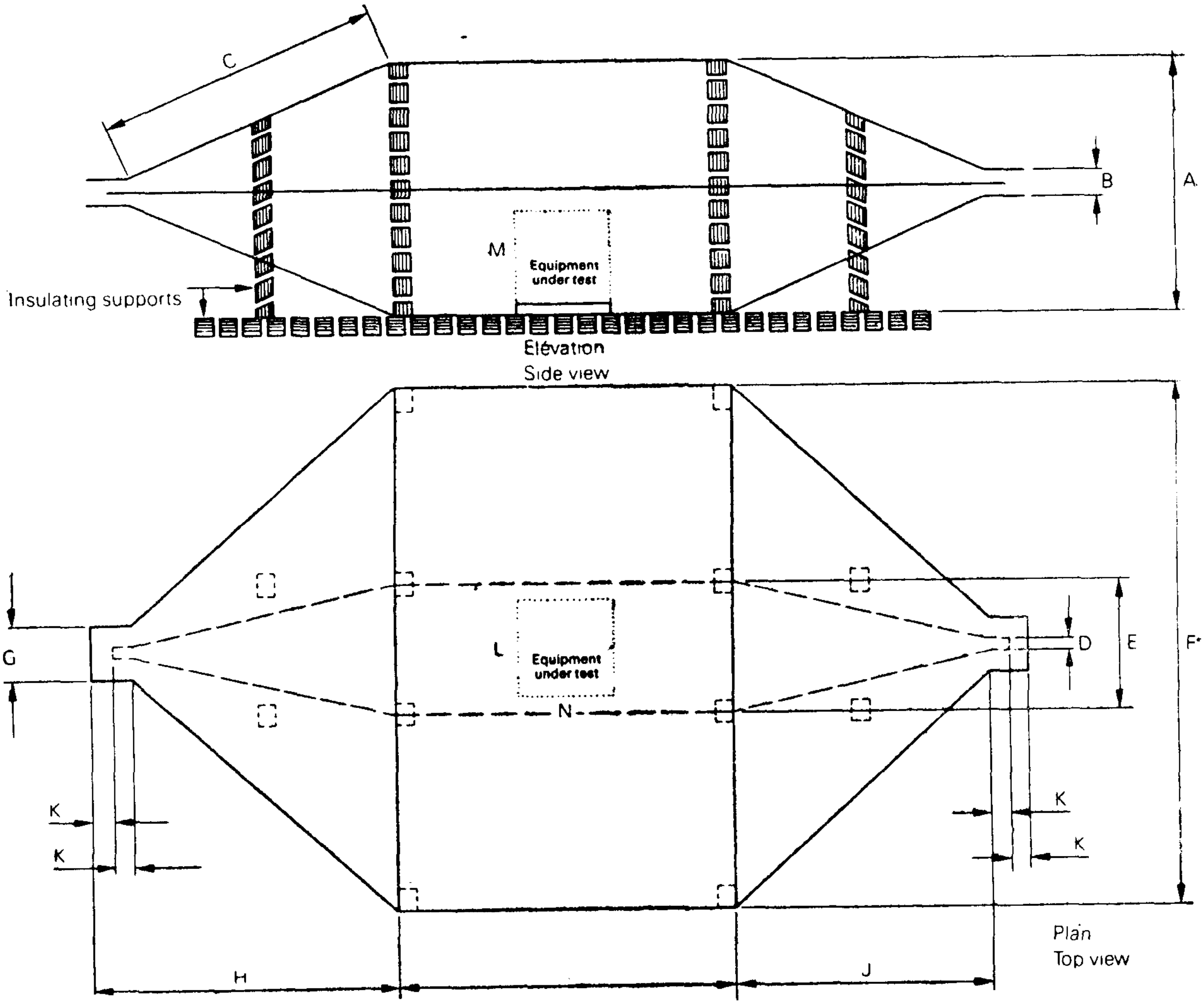
$H$ is the distance in metres between the outer conductor and the central conductor, and is equal to 0.3 m for size I and 0.6 m for Size II.

$C$ is a constant

$V_1$ is determined in the same way that the input voltage to a receiver is determined (e.g., the radio-frequency signal generator output reduced by any losses due to attenuators, cables, combining or matching networks). $V_1$ should be determined for each measuring device and each frequency used in the measurement.

If the radio-frequency signal generator output is calibrated in μV (e.m.f.), then $C$ is 0.5.

If the radio-frequency signal generator output is calibrated in μV (matched-load [ml]), then $C$ is 1.



*Dimensions in millimetres*

| | Dimensions Size I | Dimensions Size II |
|---|---|---|
| *A* | 600 | 1 200 |
| *B* | 60 | 120 |
| *C* | 658 | 1 316 |
| *D* | 31 | 62 |
| *E* | 312 | 624 |
| *F* | 1 250 | 2 500 |
| *G* | 125 | 250 |
| *H* | 700 | 1 350 |
| *I* | 800 | 1 500 |
| *J* | 600 | 1 200 |
| *K* | 50 | 75 |
| *L* | 200 | 400 |
| *M* | 250 | 500 |
| *N* | 200 | 400 |

FIG. J1. — RFCD (stripline).

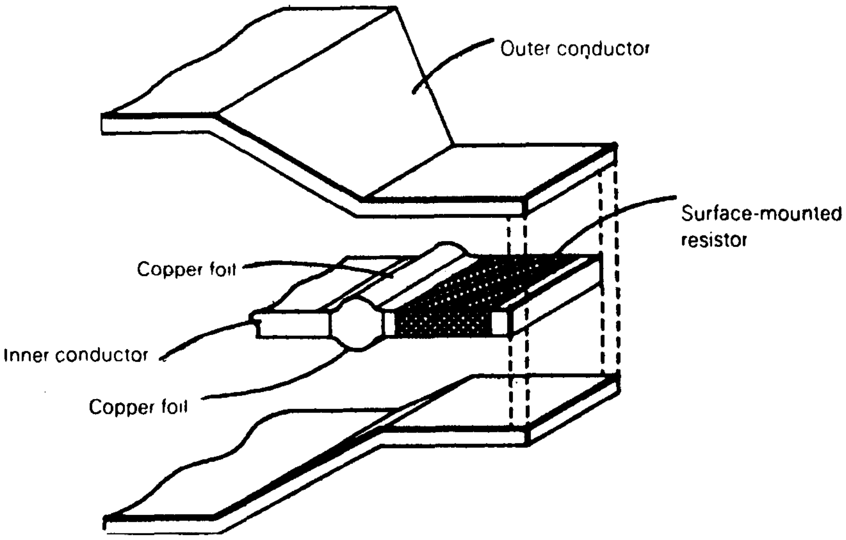


FIG. J2. — Detail of stripline loan.

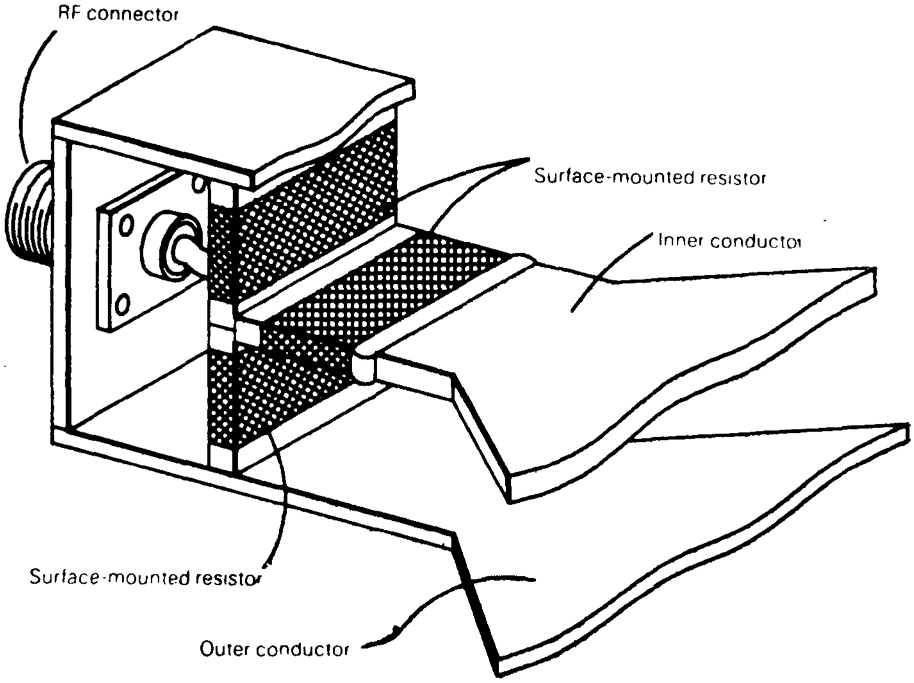


FIG. J3. — Detail of stripline input matching resistor.

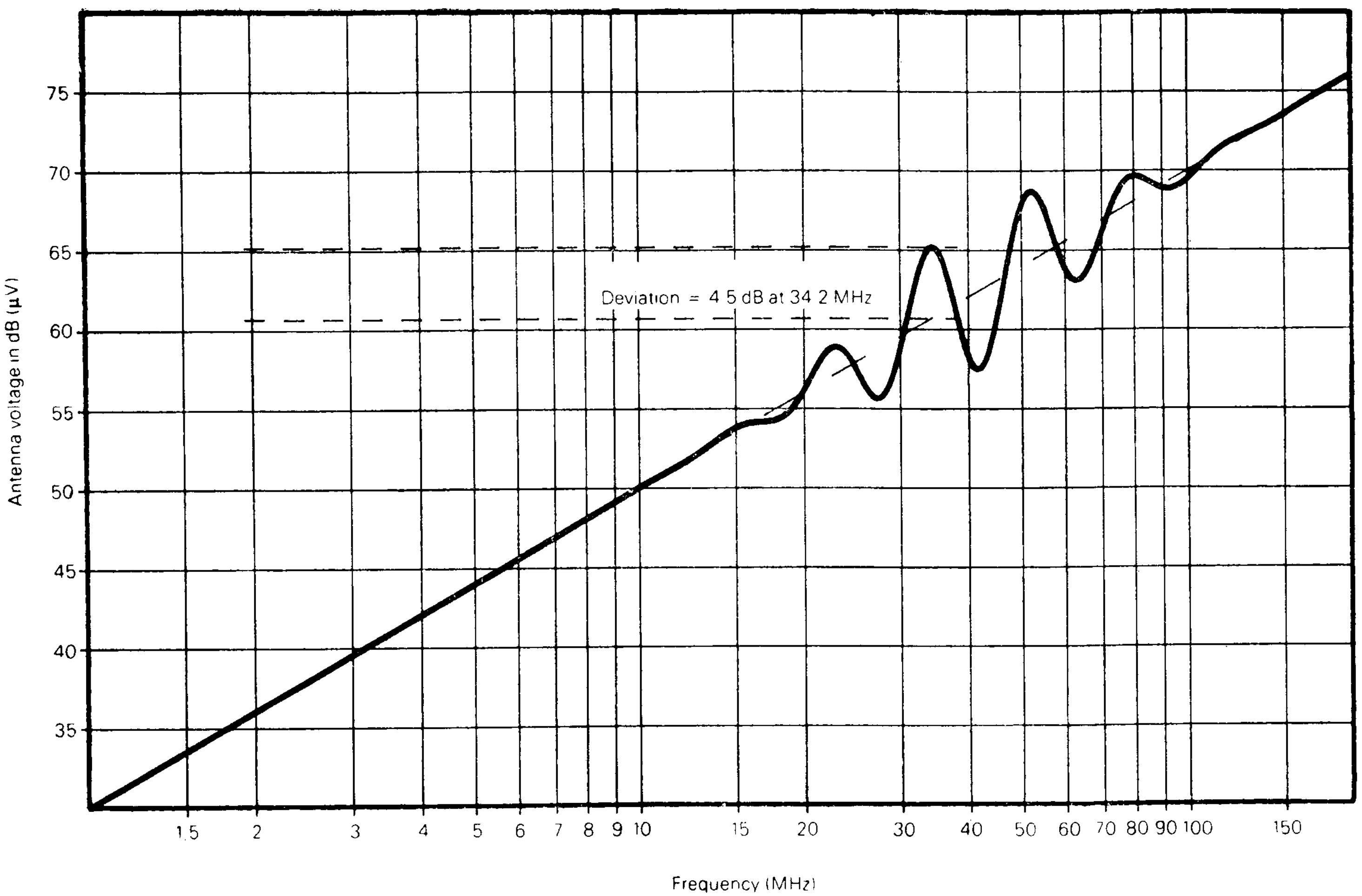


FIG. J4. — Antenna voltage versus frequency (example).

# APPENDIX K

## GUIDE FOR THE CONSTRUCTION OF A 30 m RADIATION TEST SITE FOR EQUIPMENT EMITTING RADIO-FREQUENCY ELECTROMAGNETIC ENERGY

Emission measurements can be made for all radio-frequency parameters pertaining to radiated radio-frequency electromagnetic energy, for example, transmitter radiated power, transmitter radiated spurious power, receiver radiated spurious power.

### K1. Test site characteristics

| | *Limits* |
|---|---|
| Useful frequency range: | 25 MHz to 1 000 MHz |
| Nominal site attenuation: | 20 dB to 46 dB for 25 MHz<br>52 dB to 78 dB for 1 000 MHz |

*Note.* — The nominal attenuation of the test site for a half-wave dipole is 26 dB for 25 MHz and 58 dB for 1 000 MHz. The actual attenuation may vary due to ground reflections.

| | |
|---|---|
| Equipment size limits: | 6 m maximum, excluding the antenna |
| Radiation angle limits: | Limits only apply to the horizontal plane |

See Appendix H for tests using an alternative mounting arrangement.

### K2. Radiation test site

The radiation test site shall be on level ground having uniform electrical characteristics and be free from reflecting objects over as wide an area as possible to ensure that extraneous electromagnetic fields do not affect the accuracy of the test results.

The minimum boundary of the test site shall be an ellipse having a 60 m major axis and a 52 m minor axis. The equipment under test and the transmitting antenna shall be located at the foci.

No extraneous conducting objects having any dimension in excess of 15 cm for measurements over the frequency range of 25 MHz to 300 MHz, or 5 cm for measurements over the frequency range of 300 MHz to 1 GHz, shall be in the immediate vicinity of the equipment under test or the transmitting antenna.

The distance between the vertical axis through the centre of the antenna of the equipment under test and the vertical axis through the centre of the transmitting antenna shall be 30 m.

All test equipment if located above ground shall preferably be powered by batteries. If the equipment is powered from the mains, each of the mains supply cables shall be provided with a suitable radio frequency filter. The cable connecting the filter and the measuring equipment shall be screened and shall be as short as possible. The cable connecting the filter and the supply mains shall be either screened and be at ground level, or shall be buried to a depth of approximately 30 cm.

### K3. Position of the equipment under test (see Figure K1)

A pedestal shall be placed on a turntable so that the pedestal's upper horizontal surface will be 1.5 m above ground. The equipment under test in the cabinet or housing in which it normally operates shall be placed on the upper horizontal surface of the pedestal. Both the turntable and the pedestal shall be made of non-conducting material.

For equipment having an integral antenna, place the equipment on the platform in a position which is closest to its position in normal use.

For equipment having a rigid external integral antenna, mount the equipment so that the antenna is in a vertical position.

For equipment having a non-rigid external integral antenna, mount the antenna vertically with a non-conducting support.

It shall be possible to rotate the equipment about the vertical axis through the centre of the antenna of the equipment under test. It is recommended that a platform in the form of a turntable, preferably remotely controlled should be used for this purpose.

If the equipment has a power cable, it should extend down to the turntable, and any excess cable length should be coiled on the turntable.

For information on the use of alternative mounting arrangements on this test site for equipment which is hand-held or carried on the person while in normal operation. see Appendix H.

### K4. Measuring antenna support

The measuring antenna support shall consist of a horizontal boom supported by a vertical pole, both made of non-conducting material. The boom shall project at least 1 m from the vertical pole in the direction of the equipment under test and shall be arranged so that it may be raised and lowered from 1 m to 4 m.

### K5. Measuring antenna

The measuring antenna shall be suitable for the reception of linearly polarized waves. It may consist of a half-wave dipole, the length of which is adjusted for the frequency concerned. For practical reasons, however, or to increase the sensitivity of the measurements, it may be convenient to use a number of separate fixed broadband dipoles or more complex antennas.

The measuring antenna shall be mounted at the end of the horizontal boom. The mounting shall permit the antenna to be positioned for measuring both the horizontal and the vertical components of the electrical field. The lower end of the antenna, when oriented for vertical polarization and placed in its lowest position, shall be at least 0.3 m above the ground.

The cable from the antenna shall be routed along the horizontal boom for at least 1 m, and should preferably extend, while being at ground level, at least 3 m beyond the minimum boundary of the test site before it is connected to the selective measuring device. Alternatively, the cable may be routed underground.

### K6. Auxiliary antenna

The auxiliary antenna replaces the equipment under test during part of the measurement. The auxiliary antenna shall be a half-wave dipole and shall be arranged in a manner similar to that of the measuring antenna, except that the centre of the auxiliary antenna should coincide approximately with the normal position of the centre of radiation of the equipment under test.

### K7. Radio-frequency signal generator

A well-shielded radio-frequency signal generator with a matching or combining network ( if required ) and its associated output cable, shall be placed in a position such that it will not affect the accuracy of the test results, and shall be connected to and matched to the auxiliary antenna.

At frequencies below about 60 MHz, the above condition is impossible to achieve when the antenna is arranged for vertical polarization. In this case, the lower end of the dipole shall be placed 0.3 m above ground.

## K8. Selective measuring device

The selective measuring device may be either a frequency selective voltmeter, a spectrum analyzer, or a calibrated field-strength meter, and shall be placed, together with its associated input cable, in a position such that it shall not affect the accuracy of the test results.

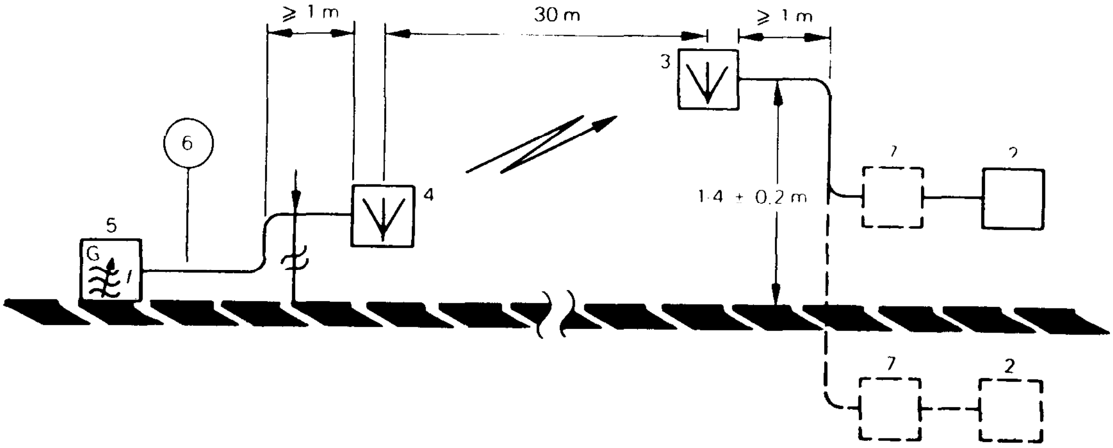


FIG. K1a.

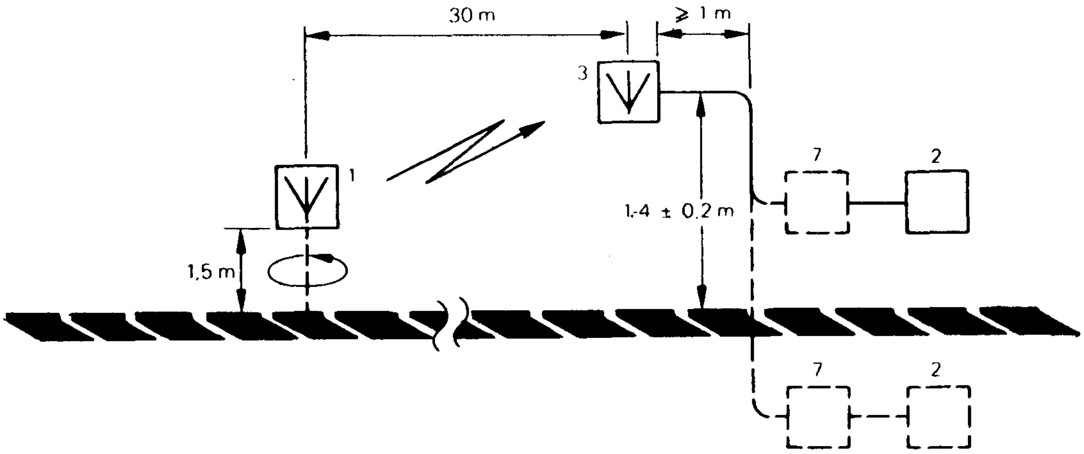


FIG. K1b.

1 = transmitter under test
2 = selective measuring device
3 = measuring antenna
4 = auxiliary antenna
5 = radio-frequency signal generator
6 = selective measuring device
7 = optional calibrated attenuator for measuring the effective radiated power, or fundamental oscillation rejection filter for measuring non-essential emissions

FIG. K1. — Measuring arrangement for transmitter at 30 m.

# APPENDIX L

## GUIDE FOR THE CONSTRUCTION OF A 3 m RADIATION TEST SITE FOR MEASUREMENTS ABOVE 100 MHz OF EQUIPMENT EMITTING RADIO-FREQUENCY ELECTROMAGNETIC ENERGY

Emmission measurements can be made for all radio-frequency parameters pertaining to radiated radio-frequency electromagnetic energy, for example, transmitter radiated power, transmitter radiated spurious power, receiver radiated spurious power.

### L1. Test site characteristics

| | *Limits* |
|---|---|
| Useful frequency range: | 100 MHz to 1 000 MHz |
| Nominal site attenuation: | 12 dB to 38 dB for 100 MHz<br>32 dB to 58 dB for 1 000 MHz |

*Note.* — The nominal attenuation of the test site for a half-wave dipole is 18 dB for 100 MHz and 38 dB for 1 000 MHz. The actual attenuation may vary due to ground reflections.

| | |
|---|---|
| Equipment size limits: | 6 m maximum, excluding the antenna |
| Radiation angle limits: | + 40° to − 10° |

See Appendix H for tests using an alternative mounting arrangement.

### L2. Radiation test site

The 3 m test site described in this standard provides consistent results regardless of time or location. It permits an accuracy over the useful frequency range comparable to that achievable on larger test sites while requiring less sensitive instrumentation than on these larger sites.

The radiation test site shall be on level ground having uniform electrical characteristics and be free from reflecting objects over as wide an area as possible to ensure that extraneous electromagnetic fields do not affect the accuracy of the test results.

A continuous ground screen ( either sheet metal or wire mesh having openings no greater than 1 cm, which should maintain good electrical contact between the wires ) shall be used to establish a uniformly conducting earth over part of the test site. The minimum ground screen area is shown in Figure L1.

No extraneous conducting objects having any dimensions in excess of 5 cm should be present within the minimum ground screen boundary. Objects between the minimum ground screen boundary and the test site boundary shall not be such as to affect the test results.

The test site shall have a turntable and a support for the measuring antenna. The distance in the horizontal plane between the vertical axis through the centre of the turntable and the vertical axis through the centre of measuring antenna mounted on its support shall be 3 m. A shelter may be provided for all or part of the test site. All such construction, except for nails, hinges, etc, having no dimension greater than 5 cm, shall be of wood, plastic, or other non-conducting material. The wood shall be impregnated to ensure minimum water absorption.

All test equipment located above ground shall preferably be powered by batteries. If the equipment is powered from the mains, each of the mains supply cables shall be provided with a suitable radio-frequency filter. The cable connecting the filter and the measuring equipment shall be screened and shall be as short as possible. The cable connecting the filter and the supply mains shall be either screened and be at ground level, or shall be buried to a depth of approximately 30 cm.

L3. **Position of the equipment under test** (see Figure L2).

The equipment in its cabinet or housing in which it normally operates shall be placed on a horizontal platform, the upper side of which is 1.5 m above the ground. The platform and its support shall be made of non-conducting material.

For equipment having an integral antenna, place the equipment on the platform in a position which is closest to its position in normal use.

For equipment having a rigid external integral antenna, mount the equipment so that the antenna is in a vertical position.

For equipment having a non-rigid external integral antenna, mount the antenna vertically with a non-conducting support.

It shall be possible to rotate the equipment about the vertical axis through the centre of the antenna of the equipment under test. It is recommended that a platform in the form of a turntable, preferably remotely controlled, should be used for this purpose.

If the equipment has a power cable, it should extend down to the turntable, and any excess cable length should be coiled on the turntable.

For information on the use of alternative mounting arrangements on this test site for equipment which is hand-held or carried on the person while in normal operation, see Appendix H.

L4. **Measuring antenna support**

The measuring antenna support shall consist of a horizontal boom supported by a vertical pole, both being made of non-conducting material. The boom shall project at least 1 m from the vertical pole in the direction of the equipment under test and shall be arranged so that it may be raised and lowered from 1 m to 4 m.

L5. **Measuring antenna**

The measuring antenna shall be suitable for the reception of linearly polarized waves. It may consist of a half-wave dipole, the length of which is adjusted for the frequency concerned. For practical reasons, however, or to increase the sensitivity of the measurements, it may be convenient to use a number of separate fixed broadband dipoles or more complex antennas.

The measuring antenna shall be mounted at the end of horizontal boom. The mounting shall permit the antenna to be positioned for measuring both the horizontal and the vertical components of the electrical field. The lower end of the antenna, when oriented for vertical polarization and placed in its lowest position, shall be at least 0.3 m above the ground.

The cable from the antenna shall be routed along the horizontal boom for at least 3 m and should preferably extend, while being at ground level, at least 3 m beyond the minimum boundary of the test site before it is connected to the selective measuring device. Alternatively, the cable may be routed underground.

**L6. Auxiliary antenna**

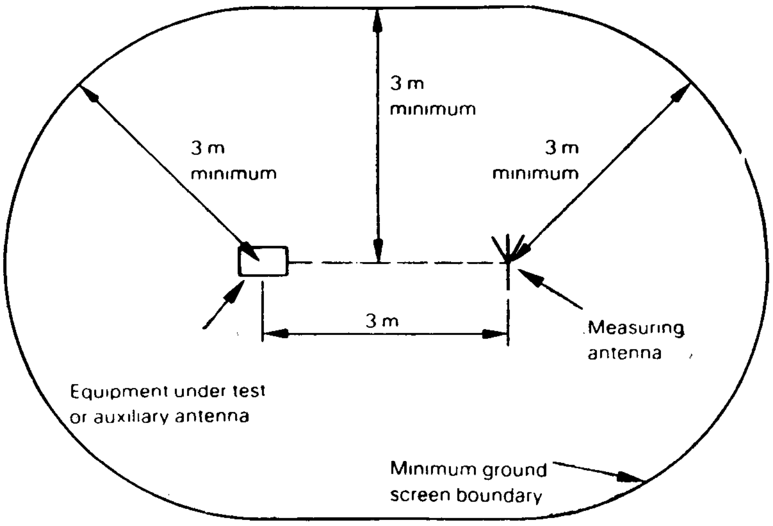
The auxiliary antenna replaces the equipment under test during part of the measurement. The auxiliary antenna shall be a half-wave dipole and shall be arranged in a manner similar to that of the measuring antenna, except that the centre of the auxiliary antenna shall coincide approximately with the normal position of the centre of radiation of the equipment under test.

**L7. Radio-frequency signal generator**

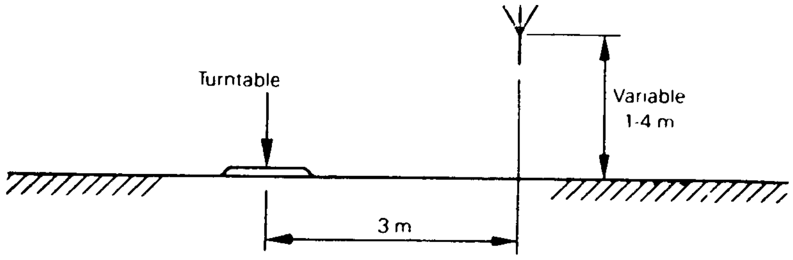
A well-shielded radio-frequency signal generator, with a matching or combining network (if required) and its associated output cable, shall be placed in a position such that it will not affect the accuracy of the test results, and shall be connected to and matched to the auxiliary antenna.

**L8. Selective measuring device**

The selective measuring device may be either a frequency selective voltmeter, a spectrum analyzer, or a calibrated field-strength meter, and shall be placed, together with its associated input cable, in a position such that it shall not affect the accuracy of the test results.



Top view



Side view

FIG. L1. — 3 m site dimensions inside the ground screen boundary.

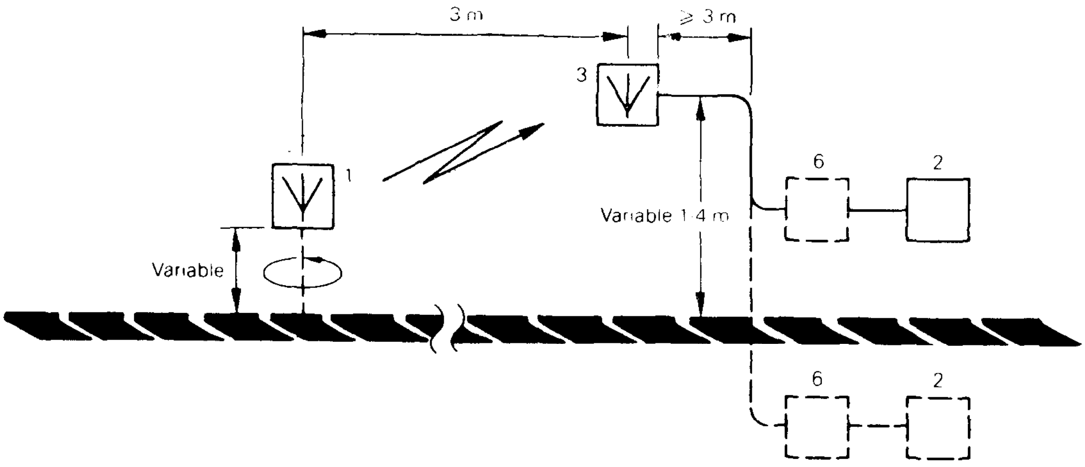


FIG. L2a. — Measuring arrangement for the equipment under test.

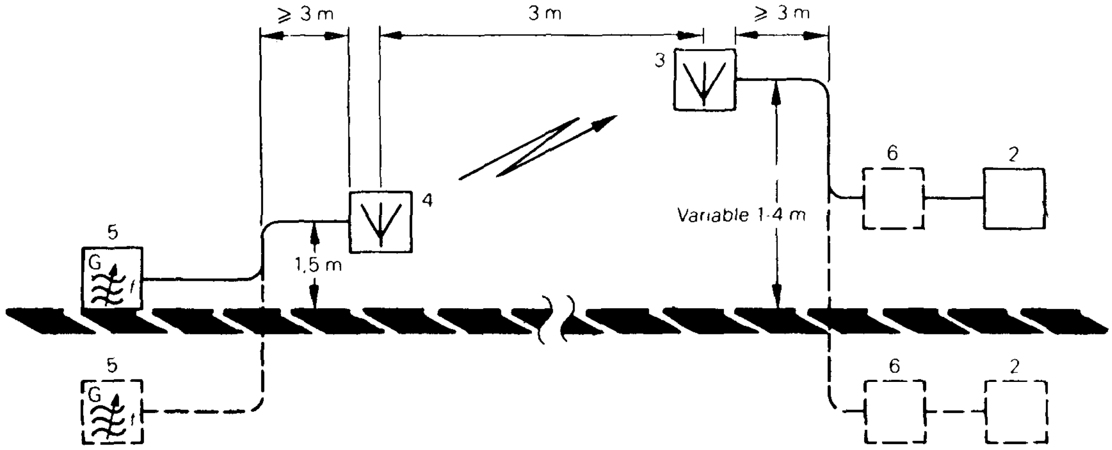


FIG. L2b. — Measuring arrangement for substitution measurement.

1 = equipment under test
2 = selective measuring device
3 = measuring antenna
4 = auxiliary antenna
5 = radio-frequency signal generator
6 = optional calibrated attenuator for measuring the effective radiated power, or fundamental oscillation rejection filter for measuring non-essential emissions

FIG. L2. — Measuring arrangement for radio-frequency emission (3 m).

# APPENDIX M

## GENERAL INFORMATION ON IMPULSIVE NOISE AND RANDOM IMPULSE GENERATOR

### M1. General

One of the major sources of impulsive interference in receivers and decoders used in the mobile services is the ignition systems of internal-combustion engines. The noise radiated by ignition systems is characterized by a great number of pulses of various amplitudes and spacings. The number of pulses per time unit exceeding a given value and measured in a given frequency band forms part of the spectrum signature of a noise environment.

The complete noise-amplitude distribution cannot be generated easily for the purpose of evaluating receiver performance. A random impulse generator can, however, be used to simulate the noise produced by city traffic. This has been found to be an effective method of measuring degradation of receiver performance due to impulsive noise.

### M2. Random impulse generator characteristics

A block diagram of an example of a random impulse generator is shown in Figure M1.

The random impulse generators used in the measurements in this standard are of the pulsed carrier type.

### M2.1 *Spectrum bandwidth*

The output spectrum should be uniform, within 0.5 dB, over the radio-frequency band-width of the receiver being measured.

The spectral amplitude for an individual carrier pulse shall be uniform, within 0.5 dB, up to a radio-input-signal-frequency $f$ (in MHz), of $\pm$ $186/\tau$, where $\tau$ is the duration of the equivalent rectangular pulse in nanoseconds. The pulse duration of the generator is an important factor to consider when determining the offset of the carrier frequency from the nominal frequency of the receiver.

### M2.2 *Output*

The output of a random impulse generator is in spectrum amplitude. The spectrum amplitude produced by impulsive noise within a given frequency band is the vector sum of the voltage within that frequency band, divided by the bandwidth; it is expressed, for example in $\mu$V/MHz or dB ($\mu$V)/MHz.

*Note.* — When the output is observed on a wide-band oscilloscope, it will be a series of short pulses of the carrier. When observed on a narrow bandwidth spectrum analyzer, it will be a $(\sin x)/x$ type frequency distribution.

The random impulse generator should be calibrated in dB ($\mu$V)/MHz with an accuracy of $\pm 1$ dB, and have a source impedance ($R_1$) equal to the impedance of the receiver (e.g., 50 Ω), including the matching and combining network. The output is a voltage measured across a test load of 50 Ω.

### M2.3 *Average impulse rate*

The random impulse generator should have an average impulse rate of 100 impulses per second (i/s).

M2.4 *Random distribution of impulses*

The time interval between impulses is random. The distribution of the impulses is given by a Poisson distribution.

One way to generate a satisfactory random distribution is to apply to an "and circuit" the output of three pseudo-random binary sequence pattern generators having lengths of 20, 21 and 22 bits, clocked at 800 bits per second. The output of the "and circuit" is used to trigger the impulse. The average impulse rate shall be 100 i/s and the probability density shall closely approximate that of a Poisson distribution.

M2.5 *Random distribution of the spectrum amplitude and amplitude correlation*

The amplitude of each carrier pulse is random. The probability density is given by a log-normal distribution that has a standard deviation of 6 dB. The amplitude correlation between carrier pulses is defined as that produced by band limited noise of 10 Hz bandwidth.

One way to generate a satisfactory random amplitude distribution is to pass flat noise through a low-pass filter with a 10 Hz cut-off frequency. The probability density of this noise shall have a normal distribution. It is used to modulate the amplitude of the carrier pulses using a modulator that has an exponential characteristic. The standard deviation of the log-normal amplitude distribution can be varied by adjusting the magnitude of the noise applied to the modulator.

## M3. Calibration of the spectrum amplitude

*a)* Connect the output of the random impulse generator to a test load and connect an oscilloscope to measure the voltage across the test load.

*b)* Set the frequency of the radio-frequency signal generator to the nominal frequency of the receiver to be measured.

*c)* Adjust the controls of the random impulse generator to the following values:

— attenuator to its minimum value,
— pulse width to 0.2 μs,
— standard deviation to 0 dB,
— pulse rate to a constant (if possible).

*Note* — Most oscilloscopes will be triggered by an impulse even if the impulses occur at random.

Record the attenuation value.

*d)* With the oscilloscope adjusted to display one pulsed carrier impulse, measure the peak voltage of the impulse. Record the peak voltage in microvolts.

*e)* Measure the time between the two points where the envelope of the impulse crosses the level that is 50% of the value recorded in Step *d)*. Record the time in microseconds.

*f)* Calculate the spectrum amplitude of the impulsive noise as follows:

$$S = \frac{\tau V}{\sqrt{2}} \left(\frac{\mu\text{V}}{\text{MHz}}\right)$$

where:

$S$ is the spectrum amplitude in μV/MHz
$V$ is the voltage recorded in Step *d)* in μV
$\tau$ is the time period recorded in Step *e)* in microseconds

This formula is valid only for that part of the frequency band in which the spectrum amplitude can be considered constant.

*Note* — An impulse of 0.2 μs duration will have a frequency distribution that is constant over a bandwidth of ±0.93 MHz.

Record the spectrum amplitude as the minimum attenuation median spectrum amplitude.

## M4. Performance verification of the random impulse generator

This verification applies to the pulse distribution and the amplitude distribution.

### M4.1 *Verification that the pulse distribution is Poisson*

### M4.1.1 *Method of measurement*

*a)* Connect the equipment as illustraded in Figure M2.

*b)* Adjust the controls of the random impulse generator as follows:

— attenuator to its minimum value,
— pulse width to 0.2 $\mu$s,
— standard deviation to 0 dB,
— pulse rate to random.

*c)* Adjust the counter to measure the number of impulses that occur within a 0.1 s period. Measure 1 000 periods at random and record in Table MI the number of periods where 5, 6,7...or 15 pulses occurred.

### M4.1.2 *Presentation of results*

If the number of periods recorded in Table MI is within the specified limits, record that the random impulse generator complies with this standard for the pulse distribution.

### M4.2 *Verification that the amplitude distribution is log-normal*

### M4.2.1 *Method of measurement*

*a)* Adjust the random impulse generator to a standard deviation of 0 dB.

*b)* Apply the radio-frequency output signal to an envelope detector with a logarithmic characteristic (e.g. a spectrum analyzer), set to zero scan mode and set to a decibel scale. Record $V$, the pulse amplitude, in decibels.

*c)* Adjust the random impulse generator to a standard deviation of 6 dB.

*d)* Measure and record the amplitude, in decibels, of 1 000 independent samples of the pulse amplitude. Take the samples at a rate of about one per second.

### M4.2.2 *Presentation of results*

*a)* For each sample *i*, calculate $Z$ where:

$$Z_i = X_i - V \quad \text{in decibels}$$

where:

$V$ is the amplitude recorded in Step *b)* of Sub-clause M4.2.1
$X_i$ is the amplitude recorded in Step *d)* of Sub-clause M4.2.1

*b)* Record in Table MII the number of samples that have a value of $Z$ that is less than the values indicated.

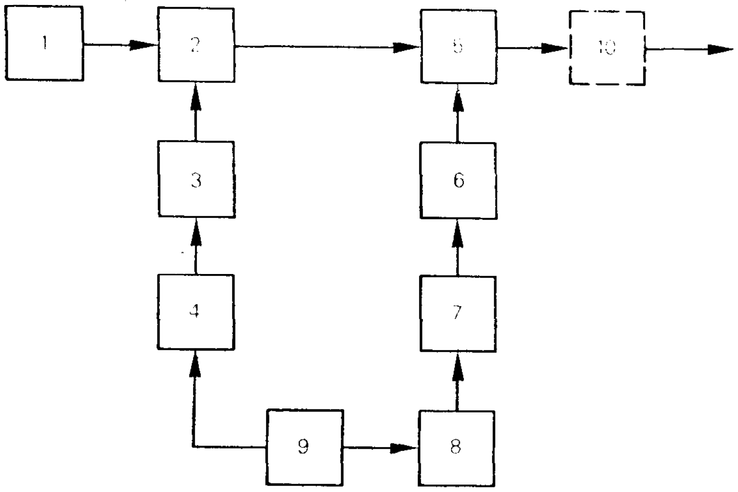
*c)* If the number of samples recorded in Table MII is within the specified limits, record that the random impulse generator complies with this standard for the log-normal amplitude distribution.

### TABLE MI

| Number of pulses per period | Lower limit | Measured (number of periods) | Upper limit |
|---|---|---|---|
| 5 | 30 | | 46 |
| 6 | 50 | | 74 |
| 7 | 72 | | 109 |
| 8 | 90 | | 136 |
| 9 | 100 | | 151 |
| 10 | 100 | | 151 |
| 11 | 90 | | 137 |
| 12 | 75 | | 114 |
| 13 | 58 | | 88 |
| 14 | 41 | | 63 |
| 15 | 27 | | 42 |

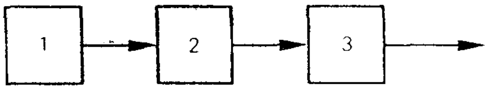
### TABLE MII

| Z (dB) (less than) | Lower limit | Measured (number of samples) | Upper limit |
|---|---|---|---|
| −15 | 1 | | 13 |
| −14 | 2 | | 19 |
| −13 | 6 | | 27 |
| −12 | 10 | | 38 |
| −11 | 18 | | 52 |
| −10 | 28 | | 71 |
| − 9 | 42 | | 95 |
| − 8 | 62 | | 125 |
| − 7 | 86 | | 162 |
| − 6 | 117 | | 205 |
| − 5 | 155 | | 254 |
| − 4 | 200 | | 309 |
| − 3 | 251 | | 370 |
| − 2 | 307 | | 434 |
| − 1 | 434 | | 500 |
| 0 | 500 | | 566 |
| 1 | 566 | | 631 |
| 2 | 630 | | 693 |
| 3 | 691 | | 749 |
| 4 | 746 | | 800 |
| 5 | 795 | | 845 |
| 6 | 838 | | 883 |
| 7 | 875 | | 914 |
| 8 | 905 | | 938 |
| 9 | 929 | | 953 |
| 10 | 948 | | 972 |
| 11 | 962 | | 982 |
| 12 | 973 | | 990 |
| 13 | 973 | | 994 |
| 14 | 981 | | 998 |
| 15 | 987 | | 999 |



1 = radio-frequency signal generator
2 = product modulator
3 = impulse generator
4 = Poisson distribution generator
5 = exponential modulator
6 = gain adjustment
7 = low-pass filter
8 = noise generator
9 = clock
10 = internal attenuator

FIG. M1. — Example of a random impulse generator.



1 = random impulse generator
2 = envelope detector
3 = frequency counter

FIG. M2. — Measuring arrangement for measurement of impulse distribution.

# APPENDIX N

## EXAMPLE OF A MAINS POWER LINE IMPEDANCE STABILIZATION NETWORK

### N1. Introduction

A mains power line impedance stabilization network is required to provide defined impedances at high frequencies between the mains terminals of the receiver and between each of these terminals and earth. The network also provides a suitable filter to isolate the receiver circuit from unwanted radio-frequency voltages that may be present on the supply mains.

The impedance of this filter section at the measuring frequency shall be sufficiently high for the combination of filter and associated network as represented in Figure N1, to give an impedance having a modulus of 150 ± 20 Ω and a phase angle not exceeding 20°, both between the terminals of the receiver and between these two terminals connected together and earth.

The symmetrical voltage is the voltage appearing between terminals A and B ( see Figure N1 ).

The asymmetrical voltage is the voltage appearing between terminal C and the earth ( see Figure N1 ).

These voltages may be represented in a theoretical vector diagram as indicated in Figure N2.

TABLE N1

Resistance, attenuation impedance values of the artificial mains network of Figure N3 ( Note 1 ) for three different input impedances Z of the measuring equipment.

| | Z=50 Ω | Z=60 Ω | Z=75 Ω |
|---|---|---|---|
| *Resistance* ( Note 2 ) | | | |
| $R_1 = R_2$ | 118.7 (120) Ω | 112.2 (110) Ω | 107.1 (110) Ω |
| $R_3 = R_5$ | 152.9 (150) Ω | 169.7 (160) Ω | 187.5 (180) Ω |
| $R_4$ | 390.7 (390) Ω | 483.9 (470) Ω | 621.4 (620) Ω |
| $R_6 = R_7$ | 275.7 (270) Ω | 230.3 (220) Ω | 187.5 (180) Ω |
| $R_8 = R_9$ | 22.8 (22) Ω | 27.6 (27) Ω | 34.5 (36) Ω |
| $R_{10} = R_{11}$ | 107.8 (110) Ω | 129.1 (130) Ω | 161.3 (150) Ω |
| $R_{12}$ | (50) Ω | (60) Ω | (75) Ω |
| *Attenuation* ( Note 3 ) | | | |
| Symmetrical $A_{sym}$ | 20 (20) dB | 20 (19.7) dB | 20 (19.8) dB |
| Asymmetrical $A_{asym}$ | 20 (19.9) dB | 20 (19.8) dB | 20 (20) dB |
| *Artificial mains network impendance* ( Note 3 ) | | | |
| Symmetrical $Z_{sym}$ | 150 (150) Ω | 150 (145.7) Ω | 150 (151.2) Ω |
| Asymmetrical $Z_{asym}$ | 150 (148) Ω | 150 (143.4) Ω | 150 (145.2) Ω |

## N2. Method of measuring interference voltage

For practical measurements, a mains power line impedance stabilization network ( also known as artificial mains network ), similar to the example given in Figure N3, may be used. This network is suitable for measuring both symmetrical ( position 1 of switch S ) and asymmetrical ( position 2 of switch S ) components with an unbalanced selective voltmeter.

*Notes 1.* — The ratio of turns of the balanced to unbalanced transformer in Figure N3, page 171, is assumed to be:

$\sqrt{\frac{2.5}{1}}$ with centre tap

*2.* — Resistance values shown in brackets are the nearest preferred values ( tolerance ± 5% )

*3.* — values shown in brackets are calculated using preferred resistance values nearest to the theoretical values.

Allowance should be made for the attenuation introduced by this network. For all pertinent values, refer to Figure N3 and Table NI in this appendix.

An additional filter section may be required to prevent unwanted radio-frequency signals, carried by the mains power line network, from significantly influencing the measurements.

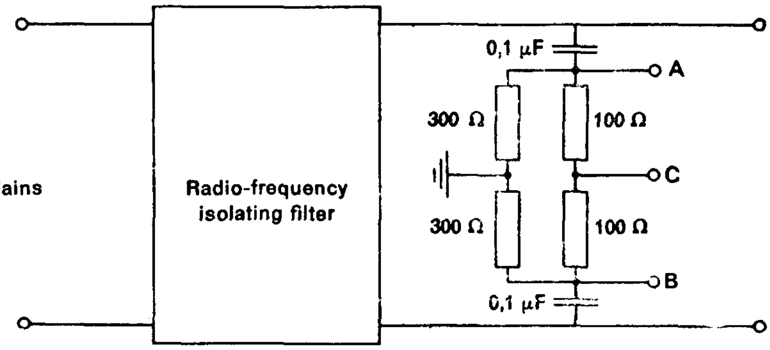


FIG. N1. — Mains power line impedance stabilization network ( also known as artificial mains network ).

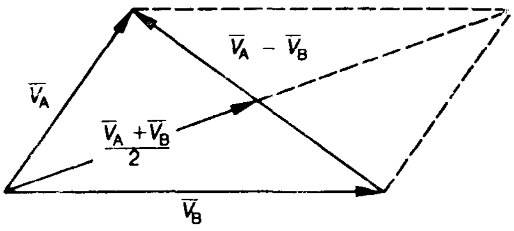
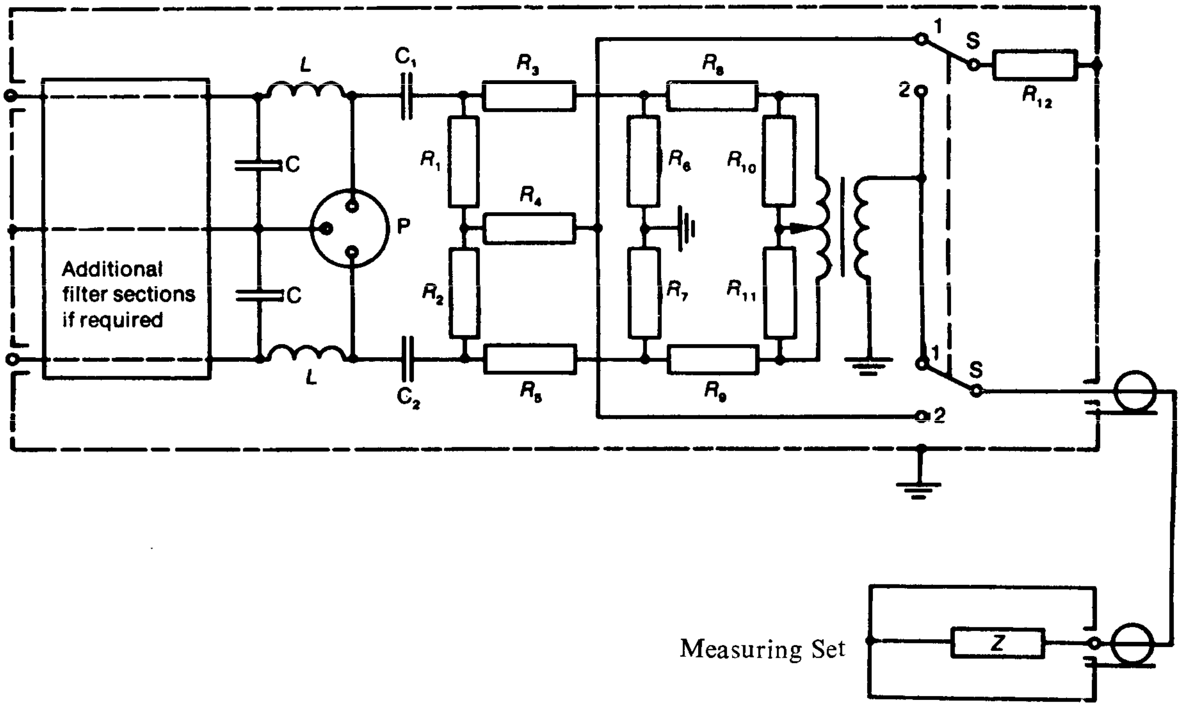

$\overline{V}_A - \overline{V}_B$
$\overline{V}_A$
$\frac{\overline{V}_A + \overline{V}_B}{2}$
$\overline{V}_B$

FIG. N2. —Vector diagram of interference voltages.



P = connections for receiver
1 = symmetrical component
2 = asymmetrical component

FIG. N3. — Example of a mains power line impedance stabilization network

# APPENDIX P

## AUDIO FREQUENCIES COMMONLY USED IN TONE-SIGNALLING SYSTEMS

### P1. General

The frequencies listed in this appendix are those used for selective signalling in the mobile services which have not already been recommended by the International Radio Consultative Committee (CCIR).

### P2. Introduction

Whereas the CCIR has cognizance and authority over operational parameters affecting the mobile services, it has not yet been judged necessary to list those audio frequencies used for selective calling except in the International Maritime Mobile Service (see CCIR Recommendation 257).

Because the choice of frequencies used for selective calling elsewhere in the mobile services requires considerable care and analysis, and because many frequencies have already been adopted for standard use but are not listed by the CCIR, it appears to be useful to collect and list those frequencies in current use.

### P3. Continuous individual tone systems

#### P3.1 *Continuous tone-controlled squelch (mute) systems (CTCSS)*

| 3.1.1 | | 3.1.2 | | 3.1.3 |
|---|---|---|---|---|
| *Group A* | | *Group B* | | *Group C* |
| Hz | | Hz | | Hz |
| 67,0 | 151,4 | 71,9 | 146,2 | 74,4 |
| 77,0 | 162,2 | 82,5 | 156,7 | 79,7 |
| 88,5 | 173,8 | 94,8 | 167,9 | 85,4 |
| 100,0 | 186,2 | 103,5 | 179,9 | 91,5 |
| 107,2 | 203,5 | 110,9 | 192,8 | |
| 114,8 | 218,1 | 118,8 | 210,7 | |
| 123,0 | 233,6 | 127,3 | 225,7 | |
| 131,8 | 250,3 | 136,5 | 241,8 | |
| 141,3 | | | | |

*Note.* — Assignments of frequencies from Group A, B or C are made in order to provide protection from interference depending upon geographic areas.

#### P3.1.4 *Other frequencies in use*

| Hz | Hz | Hz | Hz | Hz | Hz |
|---|---|---|---|---|---|
| 97,4 | 114,6 | 131,2 | 150,3 | 167,6 | 186,8 |
| 102,6 | 117,7 | 134,8 | 154,5 | 172,2 | 192,0 |
| 105,6 | 120,9 | 138,5 | 158,7 | 176,9 | 197,2 |
| 108,5 | 124,3 | 142,4 | 163,1 | 181,8 | 202,7 |
| 111,5 | 127,5 | 146,3 | | | |

P3.1.5 *Frequencies used for mobile telephone systems*

4 000 Hz, 4 010 Hz, 4020 Hz,...,6 990 Hz, 7 000 Hz

P3.2 *Receiver-voting systems*

1 950 Hz 2 250 Hz 2 325 Hz

P3.3 *Data systems*

388 Hz

P3.4 *Data transmission in radiotelephone systems*

1 950 Hz et/and 2 070 Hz

## P4. Individual tone pulse systems

P4.1 *Group A*

| Hz | Hz | Hz | Hz |
|---|---|---|---|
| 1 050 | 1 650 | 2 100 | 2 550 |
| 1 200 | 1 800 | 2 200 | 2 700 |
| 1 350 | 1 950 | 2 250 | 2 850 |
| 1 500 | 2 000 | 2 400 | 3 000 |

P4.2 *Group B*

1 575 Hz 1 725 Hz 1 875 Hz 2 025 Hz

P4.3 *Group C*

| Hz | Hz | Hz | Hz | Hz | Hz |
|---|---|---|---|---|---|
| 860 | 1 250 | 1 600 | 1 965 | 2 340 | 2 765 |
| 950 | 1 350 | 1 685 | 2 070 | 2 440 | 2 880 |
| 1 060 | 1 425 | 1 775 | 2 155 | 2 545 | 3 000 |
| 1 150 | 1 520 | 1 870 | 2 245 | 2 650 | |

P4.4 *Group D*

| Hz | Hz | Hz | Hz | Hz | Hz |
|---|---|---|---|---|---|
| 1 200 | 1 650 | 1 965 | 2 150 | 2 475 | 2 775 |
| 1 275 | 1 725 | 2 000 | 2 200 | 2 500 | 2 805 |
| 1 350 | 1 800 | 2 025 | 2 250 | 2 550 | 2 850 |
| 1 425 | 1 875 | 2 050 | 2 350 | 2 625 | 2 925 |
| 1 500 | 1 950 | 2 100 | 2 400 | 2 700 | 3 000 |
| 1 575 | | | | | |

*Note.* — The groups shown are indigenous to specific manufacturers.

P4.5 *Group E*

1 810 Hz 2 100 Hz 2 400 Hz

P4.6 *Group F*

| Hz | Hz | Hz | Hz | Hz | Hz |
|---|---|---|---|---|---|
| 102,6 | 124,3 | 150,3 | 176,9 | 208,3 | 245,1 |
| 105,6 | 127,7 | 154,5 | 181,8 | 214,0 | 251,9 |
| 108,5 | 131,2 | 158,7 | 186,8 | 219,9 | 258,8 |
| 111,5 | 134,8 | 163,1 | 192,0 | 225,9 | 266,0 |
| 114,6 | 138,5 | 167,6 | 197,2 | 232,2 | 273,3 |
| 117,7 | 142,4 | 172,2 | 202,7 | 238,6 | 280,8 |
| 120,9 | 146,3 | | | | |

### P4.7 *Group G*

| Hz | Hz | Hz | Hz | Hz | Hz |
|---|---|---|---|---|---|
| 910 | 1 120 | 1 370 | 1 750 | 2 135 | 2 800 |

## P5. Pulsed individual tone, sequential systems

### P5.1 *Below voice-band tones*

| Hz | Hz | Hz | Hz | Hz | Hz |
|---|---|---|---|---|---|
| 67,0 | 85,4 | 103,5 | 123,0 | 146,2 | 173,8 |
| 71,9 | 88,5 | 107,2 | 127,3 | 151,4 | 179,9 |
| 77,0 | 91,5 | 110,9 | 131,8 | 156,7 | 186,2 |
| 79,7 | 94,8 | 114,8 | 136,5 | 162,2 | 192,8 |
| 82,5 | 100,0 | 118,8 | 141,3 | 167,9 | 202,7 |

### P5.2 *Voice-band tones*

#### P5.2.1 *Group A*

| Hz | Hz | Hz | Hz | Hz | Hz |
|---|---|---|---|---|---|
| 517,5 | 592,5 | 667,5 | 757,5 | 832,5 | 907,5 |
| 532,5 | 607,5 | 682,5 | 772,5 | 847,5 | 922,5 |
| 547,5 | 622,5 | 697,5 | 787,5 | 862,5 | 937,5 |
| 562,5 | 637,5 | 712,5 | 802,5 | 877,5 | 952,5 |
| 577,5 | 652,5 | 727,5 | 817,5 | 892,5 | 967,5 |

#### P5.2.2 *Group B*

| Hz | Hz | Hz | Hz | Hz | Hz |
|---|---|---|---|---|---|
| 288,5 | 378,6 | 496,8 | 651,9 | 855,5 | 1 122,5 |
| 296,5 | 389,0 | 510,5 | 669,9 | 879,0 | 1 153,4 |
| 304,7 | 399,8 | 524,6 | 688,3 | 903,2 | 1 185,2 |
| 313,0 | 410,8 | 539,0 | 707,3 | 928,1 | 1 217,8 |
| 321,7 | 422,1 | 553,9 | 726,8 | 953,7 | 1 251,4 |
| 330,5 | 433,7 | 569,1 | 746,8 | 979,9 | 1 285,8 |
| 339,6 | 445,7 | 584,8 | 767,4 | 1 006,9 | 1 321,2 |
| 349,0 | 457,9 | 600,9 | 788,5 | 1 034,7 | 1 357,6 |
| 358,6 | 470,5 | 617,4 | 810,2 | 1 063,2 | 1 395,0 |
| 368,5 | 483,5 | 634,5 | 832,5 | 1 092,4 | 1 433,4 |

#### P5.2.3 *Group C*

| Hz | Hz | Hz | Hz | Hz |
|---|---|---|---|---|
| 487,5 | 787,5 | 1 087,5 | 1 387,5 | 1 687,5 |
| 637,5 | 937,5 | 1 237,5 | 1 537,5 | 1 837,5 |

### P5.2.4 *Group D*

| Hz | Hz | Hz | Hz | Hz | Hz |
|---|---|---|---|---|---|
| 495 | 725 | 1 061 | 1 550 | 2 049 | 2 898 |
| 512 | 750 | 1 098 | 1 553 | 2 121 | 3 000 |
| 530 | 776 | 1 137 | 1 600 | 2 196 | 3 106 |
| 549 | 804 | 1 177 | 1 608 | 2 274 | 3 215 |
| 568 | 832 | 1 219 | 1 664 | 2 354 | 3 329 |
| 588 | 862 | 1 261 | 1 723 | 2 437 | 3 446 |
| 609 | 892 | 1 306 | 1 784 | 2 523 | 3 568 |
| 631 | 923 | 1 352 | 1 847 | 2 612 | 3 694 |
| 653 | 956 | 1 400 | 1 912 | 2 704 | 3 824 |
| 676 | 990 | 1 449 | 1 980 | 2 799 | 3 960 |
| 700 | 1 025 | 1 500 | | | |

### P5.2.5 *Group E*

| Hz | Hz | Hz | Hz | Hz | Hz |
|---|---|---|---|---|---|
| 850 | 1 440 | 1 920 | 2 465 | 2 805 | 3 120 |
| 960 | 1 530 | 2 160 | 2 550 | 2 880 | 3 145 |
| 1 190 | 1 680 | 2 210 | 2 635 | 2 890 | 3 230 |
| 1 200 | 1 870 | 2 400 | 2 640 | 2 975 | 3 315 |

### P5.2.6 *Group F*

1 650 Hz    2 350 Hz

### P5.2.7 *Group G*

2 200 Hz

### P5.2.8 *Group H*

| Hz | Hz | Hz | Hz | Hz | Hz |
|---|---|---|---|---|---|
| 960 | 1 197 | 1 358 | 1 540 | 1 747 | 1 981 |
| 1 022 | 1 275 | 1 446 | 1 640 | 1 860 | 2 110 |
| 1 124 | | | | | |

### P5.2.9 *Group I*

| Hz | Hz | Hz | Hz | Hz | Hz |
|---|---|---|---|---|---|
| 805 | 1 060 | 1 530 | 1 830 | 2 200 | 2 600 |
| 885 | 1 270 | 1 670 | 2 000 | 2 400 | 2 900 |
| 970 | 1 400 | | | | |

### P5.2.10 *Group J*

| Hz | Hz | Hz | Hz | Hz | Hz |
|---|---|---|---|---|---|
| 250 | 291,67 | 333,33 | 375 | 416,67 | 458,33 |
| 258,33 | 300 | 341,67 | 383,33 | 425 | 466,67 |
| 266,67 | 308,33 | 350 | 391,67 | 433,33 | 475 |
| 275 | 316,67 | 358,33 | 400 | 441,67 | 483,33 |
| 283,33 | 325 | 366,67 | 408,33 | 450 | 491,67 |

P5.2.11 *Group K*

| Hz | Hz | Hz | Hz | Hz | Hz |
|---|---|---|---|---|---|
| 459 | 741 | 1 023 | 1 305 | 1 587 | 1 869 |
| 600 | 882 | 1 164 | 1 446 | 1 728 | 2 010 |

P5.2.12 *Group L*

| Hz | Hz | Hz | Hz | Hz | Hz |
|---|---|---|---|---|---|
| 313,3 | 400,0 | 510,7 | 652,0 | 832,5 | 1 062,9 |
| 339,9 | 433,9 | 554,0 | 707,4 | 903,1 | 1 153,3 |
| 368,7 | 470,8 | 601,0 | 767,4 | 979,8 | |

P5.2.13 *Group M*

| Hz | Hz | Hz | Hz | Hz |
|---|---|---|---|---|
| 370 | 550 | 825 | 1 240 | 1 860 |
| 450 | 675 | 1 010 | 1 520 | 2 280 |

P5.2.14 *Group N*

| Hz | Hz | Hz | Hz | Hz | Hz |
|---|---|---|---|---|---|
| 1 060 | 1 270 | 1 530 | 1 830 | 2 200 | 2 600 |
| 1 160 | 1 400 | 1 670 | 2 000 | 2 400 | 2 800 |

P5.2.15 *Voice-band teleprinter systems*

1 366,0 Hz 1 612,5 Hz 1 640,0 Hz

P5.2.16 *Mobile status display*

1 612,9 Hz 2 025 Hz 2 225 Hz

P5.2.17 *Touch-tone, central office to central office*

| Hz | Hz | Hz | Hz | Hz | Hz |
|---|---|---|---|---|---|
| 700 | 900 | 1 100 | 1 300 | 1 500 | 1 700 |

*Note.* — These frequencies are listed because they are used frequently in services rated to the mobile services.

P5.2.18 *Base-station wire line on radio-frequency link control*

| Hz | Hz | Hz | Hz | Hz | Hz |
|---|---|---|---|---|---|
| 1 050 | 1 350 | 1 650 | 1 850 | 2 050 | 2 450 |
| 1 150 | 1 450 | 1 750 | 1 950 | 2 175 | 2 750 |
| 1 250 | 1 550 | | | | |

*Note.* — The groups shown are indigenous to specific manufacturers.

## P6. Simultaneous tone systems

P6.1 *Touch-tone, subscriber to central office*

P6.1.1 *Group A*

| Hz | Hz | Hz | Hz |
|---|---|---|---|
| 697,0 | 852,0 | 1 209,0 | 1 477,0 |
| 770,0 | 941,0 | 1 336,0 | 1 633,0 |

### P6.1.2 *Group B*

| Hz | Hz | Hz | Hz | Hz | Hz |
|---|---|---|---|---|---|
| 501 | 708 | 1 000 | 1 295 | 1 677 | 2 172 |
| 547 | 772 | 1 090 | 1 412 | 1 828 | 2 367 |
| 596 | 842 | 1 188 | 1 539 | 1 993 | 2 580 |
| 650 | 917 | | | | |

### P6.1.3 *Group C*

| Hz | Hz | Hz | Hz | Hz | Hz |
|---|---|---|---|---|---|
| 1 060 | 1 270 | 1 530 | 1 830 | 2 200 | 2 600 |
| 1 160 | 1 400 | 1 670 | 2 000 | 2 400 | 2 900 |

## P7. **Simultaneous tone, sequential systems**

### P7.1 *Group A*

| Hz | Hz | Hz | Hz | Hz | Hz |
|---|---|---|---|---|---|
| 679 | 852 | 941 | 1 209 | 1 336 | 1 500 |
| 700 | 900 | 1 100 | 1 300 | 1 477 | 1 700 |
| 770 | | | | | |

### P7.2 *Group B*

| Hz | Hz | Hz | Hz | Hz | Hz |
|---|---|---|---|---|---|
| 346,7 | 426,6 | 524,8 | 645,7 | 794,3 | 977,2 |
| 358,9 | 441,6 | 543,3 | 668,3 | 822,2 | 1 011,6 |
| 371,5 | 457,1 | 562,3 | 691,8 | 851,1 | 1 047,1 |
| 384,6 | 473,2 | 582,1 | 716,1 | 881,0 | 1 084,0 |
| 398,1 | 489,8 | 602,6 | 741,3 | 912,0 | 1 122,1 |
| 412,1 | 507,0 | 623,7 | 767,4 | 944,1 | 1 161,4 |

### P7.3 *Group C--Touch-tone*

| Hz | Hz | Hz | Hz |
|---|---|---|---|
| 697,0 | 852,0 | 1 209,0 | 1 477,0 |
| 770,0 | 941,0 | 1 336,0 | 1 633,0 |

### P7.4 *Group D*

435 Hz 558Hz 713 Hz 914 Hz 1 170 Hz

### P7.5 *Group E*

| Hz | Hz | Hz | Hz | Hz | Hz |
|---|---|---|---|---|---|
| 1 124 | 1 275 | 1 446 | 1 640 | 1 860 | 2 110 |

*Note.* — The groups shown are indigenous to specific manufacturers.

## P8. **Pulsed individual tone systems**

### P8.1 *Group A*

600 Hz 1 500 Hz 1 800 Hz 2 000 Hz 2 805 Hz

### P 8.2 *Group B*

590 Hz 1 500 Hz 2 805 Hz

P8.3 *Group C*

600 Hz 1 336 Hz 1 500 Hz 1 633 Hz 2 150 Hz

P8.4 *Group D*

1 600 Hz 2 000 Hz 2 400 Hz

*Note.* — The groups shown are indigenous to specific manufacturers.

## P9. Pulsed individual tone, sequential systems

P9.1 *Group A*

| Hz | Hz | Hz | Hz | Hz | Hz |
|---|---|---|---|---|---|
| 935 | 1 615 | 2 635 | 3 345 | 6 105 | 8 145 |
| 1 105 | 1 955 | 2 800 | 3 855 | 6 615 | 8 655 |
| 1 275 | 2 125 | 2 975 | 4 365 | 7 125 | 9 165 |
| 1 500 | 2 295 | 3 145 | 4 875 | 7 635 | 9 675 |
| 1 600 | 2 500 | 3 315 | | | |

P9.2 *Group B*

| Hz | Hz | Hz | Hz | Hz | Hz |
|---|---|---|---|---|---|
| 420 | 900 | 1 380 | 1 860 | 2 340 | 2 805 |
| 425 | 935 | 1 445 | 1 955 | 2 460 | 2 820 |
| 540 | 1 020 | 1 500 | 1 980 | 2 465 | 2 940 |
| 595 | 1 105 | 1 615 | 2 100 | 2 580 | 2 975 |
| 660 | 1 140 | 1 620 | 2 125 | 2 635 | 3 060 |
| 765 | 1 260 | 1 740 | 2 220 | 2 700 | 3 180 |
| 780 | 1 275 | 1 785 | 2 295 | | |

P9.3 *Group C*

| Hz | Hz | Hz | Hz |
|---|---|---|---|
| 600 | 1 336 | 1 700 | 2 150 |
| 1 100 | 1 500 | 1 800 | 2 805 |
| 1 300 | 1 633 | 2 000 | |

P9.4 *Group D — Five-tone sequential systems*

| Hz | Hz | Hz | Hz |
|---|---|---|---|
| 1 060 | 1 400 | 1 830 | 2 400 |
| 1 160 | 1 530 | 2 000 | 2 600 |
| 1 270 | 1 670 | 2 200 | |

*Note.* — The groups shown are indigenous to specific manufacturers.